



# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

## **THESIS**

**FRACKING: UNINTENDED CONSEQUENCES FOR  
LOCAL COMMUNITIES**

by

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December 2016

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**FRACKING: UNINTENDED CONSEQUENCES FOR LOCAL COMMUNITIES**

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Submitted in partial fulfillment of the  
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## **ABSTRACT**

The advent of hydraulic fracturing and the ability to bore horizontal wells have changed the energy industry for better and worse since 2005. Advancements have dramatically increased the extraction of oil from shale, but the controversial process, commonly known as “fracking,” has transformed North Dakota’s Bakken into a major producer of oil that has affected global oil markets. The questions asked in this thesis are as follows: What are the effects of unconventional shale oil exploration on local communities? How can they prepare for, prevent, mitigate, and recover from the socioeconomic impacts associated with shale oil exploration?

What happened at the Bakken served as a case study to evaluate the holistic impact of fracking on the environment and socioeconomics of local communities at the epicenter of shale oil production. This study included an evaluation of crucial environmental issues: water consumption, water quality, air quality, wastewater disposal, and seismic activity in western North Dakota. Socioeconomic concerns comprised population growth, housing availability, employment rate, community growth, taxes, infrastructure needs, and crime rate. An analysis of these impacts leads this thesis to offer six recommendations that local decision makers should consider as they strive to implement risk-reduction strategies and policies for their communities.

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## **LIST OF ACRONYMS AND ABBREVIATIONS**

BLM	Bureau of Land Management
CO <sub>2</sub>	carbon dioxide
CRS	Congressional Research Service
EPA	Environmental Protection Agency
FBI	Federal Bureau of Investigation
GAO	Government Accountability Office
mb/d	million barrels per day
NDDOT	North Dakota Department of Transportation
NDIC: Oil and Gas	North Dakota Industrial Commission: Oil and Gas Division
NDSU	North Dakota State University
NORM	naturally occurring radioactive materials
NO <sub>x</sub>	nitrogen oxides
NRC	National Research Council
O <sub>3</sub>	ozone
OGW	oil and gas wastewater
PM	particle matter
SO <sub>2</sub>	sulfur dioxide
SWDA	Safe Water Drinking Act
TDS	total dissolved solids
UCR	uniform crime rate
USGS	United States Geologic Survey

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## **EXECUTIVE SUMMARY**

After a rise in the global market price of oil and decades-long U.S. reliance on imported oil to meet demands, advancements occurred in the extraction of shale oil. The combination of improvements in hydraulic fracturing, also known as fracking, and the ability to bore wells horizontally created a boom in the energy sector, the epicenter of which was the Bakken shale oil formation in western North Dakota.

Different from conventional oil production, the extraction of oil from shale is known as unconventional oil production, which pumps out a pocket of trapped oil. As with any advancement, its unintended consequences continue to be the subject of research. Since fracking is a relatively new process, speculation and controversy surround it, which inhibits decision makers who must make difficult policy decisions that can have lasting impacts. The primary question asked in this thesis is: What are the effects of unconventional shale oil exploration on local communities?

To answer the research question, this thesis took the form of an analysis of a qualitative case study of the Bakken, the largest shale oil formation in the United States. It includes an identification of causation effects on the local environment, as well as an analysis of the socioeconomic impacts at the local level and their correlation with the boom-and-bust cycle. The case study included the identified environmental concerns of water consumption, groundwater and surface water contamination, handling of produced water, spills, air quality, and seismic activity. The identified socioeconomic concerns comprised the effects of population in-migration, housing demands, economic changes, tax revenues, infrastructure needs, and crime. Based on the data, a qualitative analysis revealed patterns matching previous research, the how and why of events, and trends in the chronology of events.

Oil prices spiking to new highs typically cause a boom: a rapid influx of people looking for high-paying jobs, an abrupt rise in the housing market, income disparity, the displacement of long-time residents, atypical variance in community demographics, an increase in crime, the rapid expansion of infrastructure, an influx of tax revenue, and the

deviation of long-term investments from their expected growth pattern. As oil prices drop, the bust ensues: The local economy retracts, causing an increase in local debt. At the time of this writing, the extent of local impacts to the Bakken were emergent.

This research revealed local impacts from unconventional oil production, albeit to varying degrees. Fracking has contributed to the consumption of trillions of gallons of fresh water. Spills have contaminated the soil and surface water with a potential for contaminating groundwater. The release of natural gas has globally polluted air quality. The rapid influx of workers to the area has caused housing prices and crime to rise while many original residents have become either physically or emotionally displaced from their own community. Regardless, fracking has facilitated the creation of new infrastructure in the area.

Six policy and governance recommendations have emerged for decision makers for the prevention of, preparation for, and mitigate of known risks from the findings of this and previous research on fracking. As many long-term impacts remain unknown, the subject of fracking will continue to evolve, resulting in increased clarity. The lessons gained from the case study on the Bakken can frame the discussion and improve decisions for the next community leaders who face the unintended consequences of fracking.

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## **I. INTRODUCTION**

### **A. THE IMPORTANCE OF OIL TO THE U.S. ECONOMY**

For decades, U.S. oil consumption exceeded domestic production, creating a net demand for oil imports.<sup>1</sup> Recent technological improvements in oil extraction have made it more economically feasible to produce oil by hydraulic fracturing, generating a boom in domestic production. The method of hydraulic fracturing to extract oil is a process commonly called fracking.<sup>2</sup> Those improvements have created an opportunity to increase domestic oil production, which reduces the need to import foreign oil (see Figure 1). A Government Accountability Office (GAO) report indicated that shale oil development, also known as unconventional oil production or fracking, could limit the need to import expensive oil and help to reduce the U.S. trade deficit.<sup>3</sup> Decreased reliance on imported oil and increased domestic production have substantial benefits, including job creation, increased prosperity, and increased tax and royalty payments to the local, state, and federal government.<sup>4</sup>

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<sup>1</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks* (GAO-12-732) (Washington, DC: United States Government Accountability Office, 2012), 1.

<sup>2</sup> Ibid.

<sup>3</sup> Ibid.

<sup>4</sup> *Unconventional Oil and Gas Production: Opportunities and Challenges of Oil Shale Development: Hearings before the Subcommittee on Energy and Environment, Committee on Science, Space, and Technology* (2012) (statement of Anu K. Mittal).

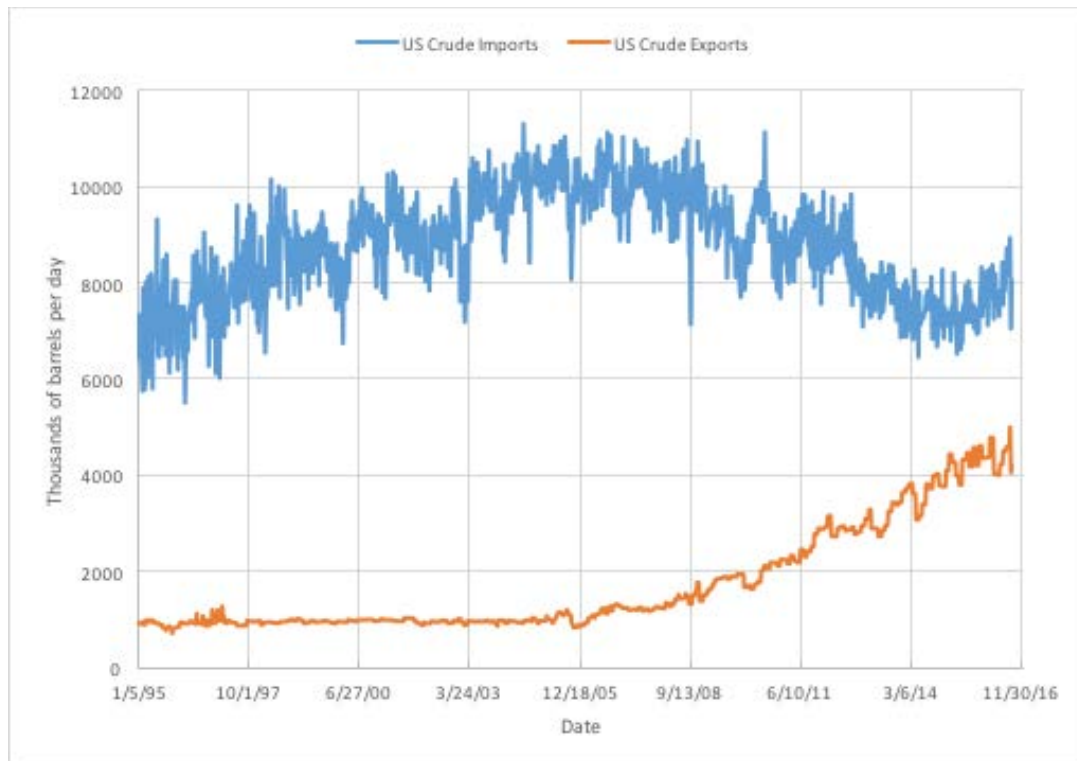


Figure 1. Plot of Oil Imports (Blue) and Exports (Orange) from 1995 to the Present, Showing a Recent Convergence of Domestic Supply and Demand.<sup>5</sup>

The use of oil extracted via fracking has come at a time when production from conventional wells has decreased. Although an approximate 5% decrease has occurred in production from older conventional fields, a loss of 3 to 4 million barrels per day (mb/d), an increase in production from unconventional sources, such as shale, has offset that loss.<sup>6</sup> Since 2005, the net effect has generated an increase in oil production by approximately 75 mb/d.<sup>7</sup> High global oil prices drove the market for unconventional oil extraction,<sup>8</sup> leading to unprecedented increases in shale oil production.<sup>9</sup> From 2007 to

<sup>5</sup> Adapted from “Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays,” accessed March 26, 2016, <http://www.eia.gov/analysis/studies/usshalegas/>.

<sup>6</sup> James W. Murray and Jim Hansen, “Peak Oil and Energy Independence: Myth and Reality,” *EOS, Transactions American Geophysical Union* 94, no. 28 (2013): 245.

<sup>7</sup> *Ibid.*, 247.

<sup>8</sup> *Ibid.*

<sup>9</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 26.

2011, annual shale oil production saw a five-fold increase, from 39 to roughly 217 million barrels.<sup>10</sup> Figure 2 plots data from the U.S. Energy Information Administration, showing the dramatic increase in oil production by fracking since 2009. In fact, fracking constitutes over 50% of U.S. domestic oil production. A close look at Figure 2 shows peak production in 2014, followed by a rapid drop to production levels at the time of this writing.

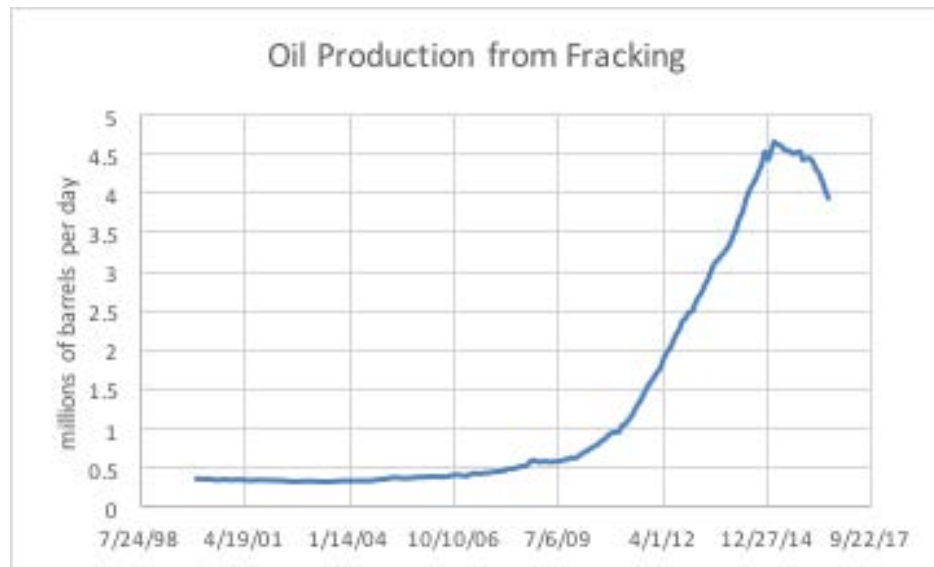


Figure 2. Plot of Oil Production by Fracking from 1998 to the Present Shows a Dramatic Increase Beginning in 2007 with a Peak in 2014 and Subsequent Drop to Current Production Levels.<sup>11</sup>

## B. WHAT IS FRACKING?

### 1. The Fracking Process

Shale oil extraction, or fracking, is both more complicated and expensive than conventional oil well extraction and requires additional technology.<sup>12</sup> Deep in the earth's

<sup>10</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 25.

<sup>11</sup> Adapted from "Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays."

<sup>12</sup> Murray and Hansen, "Peak Oil and Energy Independence," 245.

shale and porous rock formations are pockets of trapped oil.<sup>13</sup> To extract shale oil, the first step is to purchase the land rights and build a wellpad with all necessary infrastructure to pump, collect, and store the oil. With the support infrastructure in place, a wellbore is established by drilling vertically into the earth to reach the shale formation, then drilling horizontally into the shale. The horizontal drilling typically extends 2,000 to 6,000 feet but can be as long as 12,000 feet.<sup>14</sup> When drilling is complete, the drill bit is removed, and the metal casing and cement are inserted to secure a metal casing pipe, which creates a sealed system that allows for the pressurization of the well to enable the hydraulic fracturing process. As smaller and smaller casing pipe is inserted into the borehole, cement serves to bond the pipe to the formation.<sup>15</sup>

To extract shale oil, steam or a liquid called a fracturing fluid is injected at high pressure into the formation through the casing pipe. While proprietary, fracturing fluid is likely a combination of hydrochloric acid, ethylene glycol, water, and fracturing sand.<sup>16</sup> The pressurized steam or fluid expands into any natural fractures in the formation and creates new fractures. When the pressure is reduced, oil pushes back through the new or expanded fractures, and is then pumped to the surface. The end product, called produced water, contains the fracturing fluid, water, oil, and other gases.<sup>17</sup> Oil is separated from this mixture of fluids, and the produced water, absent the oil but still containing a mixture of chemicals, is then stored in retention pools, called impoundment areas, injected into other underground wells, trucked to a disposal site or water treatment facility, or reused for other processes.<sup>18</sup>

Once the well produces oil or natural gas, the equipment necessary for the fracking process is removed, and only the infrastructure needed to pump, collect, and

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<sup>13</sup> United States Government Accountability Office, *Energy-Water Nexus: Information on the Quantity, Quality, and Management of Water Produced during Oil and Gas Production* (GAO-12-156) (Washington, DC: United States Government Accountability Office, 2012), 5.

<sup>14</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 9.

<sup>15</sup> *Ibid.*, 8.

<sup>16</sup> *Ibid.*, 12.

<sup>17</sup> *Ibid.*

<sup>18</sup> *Ibid.*



store the oil remains. As well production decreases, the well can be restimulated by repeating the hydraulic fracturing process.<sup>19</sup> Once the useful life of the well is over, the casing is sealed.

Regulation of shale oil production and the fracking process is governed by local, state, and federal laws.<sup>20</sup> The majority of fracking, which occurs on private land, is governed by local or state regulations and their associated agencies. A federal agency, such as the Bureau of Land Management (BLM), oversees the fracking that occurs on federal land; however, federal regulations can also apply locally because many of the federal regulations that apply to off-shore conventional oil production also apply to unconventional oil production.<sup>21</sup>

## **2. Defining the Problem**

As with many new advancements, predicting and sometimes detecting all the consequences can be difficult, especially when such impacts are studied individually instead of in aggregate. As fracking had generated so much domestic income and its consequences were masked by the readily apparent benefits, a wide variety of opinion and public policies have arisen. This thesis includes an examination of the issue from a local perspective and a discussion of local impacts, both positive and negative, with the aim of providing a set of recommendations useful to guide policy making by local government and agencies.

Much of the available research provides high quality information and trends but does not aggregate that information into a comprehensive analysis of the adverse effects that boom-and-bust technologies can level on local communities. Those adverse effects present a homeland security concern: Chemicals used during the fracking process and the shale oil itself present public health concerns to the communities in the drilling areas with little known or published on the potential long-term effects.

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<sup>19</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 13.

<sup>20</sup> Ibid.

<sup>21</sup> Ibid.

A gap currently exists in the understanding of short- and long-term unintended consequences for communities that choose to allow fracking. In addition, until those consequences are viewed holistically, the local communities will not be fully prepared. Aside from the positive economic impact, the advent of a fracking boom generates an influx of workers, increased traffic, increased demand for housing and social services, planning and zoning issues, infrastructure demands, and socioeconomic concerns. Communities must plan for all these changes if they are to be properly informed prior to making any policy decisions related to permitting the process. The unintended costs of extraction and adverse consequences from environmental interference, as well as socioeconomic flux, have yet to be explored and properly juxtaposed to the economic gains. This research extends beyond previous research, which focused only on the individual risks of fracking. Instead, this research expands the consequence measures with an examination of the broader impacts to a community to create a more accurate representation of any interconnected events associated with fracking.

For local communities to be prepared properly for any ancillary effects of fracking, additional research on both short- and long-term consequences is essential. As societal effects and their measurements were in emergent stages at the time of this writing, analyzing the available data was critical so communities could make informed decisions before permitting fracking operations. For that purpose, a descriptive research paradigm was instrumental in answering the primary research question: What are the effects of unconventional shale oil exploration on local communities?

An exploratory research paradigm was essential in answering ancillary research questions that were designed to identify the most effective ways to reduce identified negative impacts. The ancillary questions were how can communities prepare for, prevent, or mitigate the environmental impacts of shale oil exportation? How can communities prepare for, prevent, mitigate, and recover from the socioeconomic impacts associated with shale oil exploration?

According to the GAO, the three largest onshore shale oil producing formations are the Bakken<sup>22</sup> in western North Dakota, the Eagle Ford in southern Texas, and the Niobrara extending into Colorado, Kansas, Nebraska, and Wyoming. Since Bakken shale oil in Williston, North Dakota accounts for more than 65% of all U.S. shale oil, it is the focus of this thesis.<sup>23</sup> The presumption was that Williston represents a case-study city useful in informing other communities; furthermore, although this thesis covered the specific case of fracking, the results have been discussed in a broader context of any boom-and-bust technology that involved short-term exploitation of a natural resource. An additional presumption was that because the Bakken is the largest shale-oil field, Williston could serve as a representative test case. If any undesirable consequences of fracking exist, they will most certainly occur in the largest fracking community. The purposes of this thesis were to examine holistically the multiple community impacts associated with shale oil and to use this case study to identify recommended actions that would decrease any evident negative impacts.

### **C. RESEARCH DESIGN**

To examine the unintended consequences of shale oil extraction resulting from the hydro-fracking process on local communities, an embedded case study of the community of Williston, North Dakota, yielded patterns of impacts associated with fracking. According to Robert Yin, a single case study is ideal when it represents a “critical case.”<sup>24</sup> The community of Williston and the Bakken shale oil play is a critical case because it is the largest and most developed fracking community in the US and is thus highly generalizable to other communities.<sup>25</sup>

The basis of the selection of the Williston, North Dakota area, and the Bakken shale oil case study, was the overall significance of the shale oil formation. According to

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<sup>22</sup> The Bakken is named after Henry O. Bakken who discovered oil on his farmstead northeast of Tioga, North Dakota from wells drilled in 1951 and 1952.

<sup>23</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 27.

<sup>24</sup> Robert K. Yin, *Case Study Research: Design and Methods*, 4th ed., Applied Social Research Methods, v. 5 (Los Angeles: Sage Publications, 2009), 47.

<sup>25</sup> Ibid.

the United States Geologic Survey (USGS), the Bakken is the “largest ‘continuous’ oil accumulation ever assessed by the USGS.”<sup>26</sup> Williston, a rural community with a population of 24,562 as of 2014, has changed dramatically since 2008 when the oil industry leaders determined that the Bakken shale oil play held approximately four billion barrels of crude oil.<sup>27</sup> The discovery resulted in an economic boom for the community and the region, which made it an ideal case study for this thesis. Adding interest is that Bakken crude oil has proven to be more flammable than other kinds of crude and made its transport a worst-case scenario.

#### **D. STUDY LIMITATIONS**

The scope of this research concerned what local communities can do, or what state agencies can do, in support of local communities to mitigate associated risks. The federal government has a role and responsibility to mitigate risks, and that role should be evaluated; however, improvements to federal support were not examined for the purpose of this thesis because a local or state government can do little to influence federal regulations. When it comes to environmental concerns, this thesis focused only on air, water, and seismic activity and how the state or local governments regulate, inspect, or measure any impacts. As for socioeconomic concerns, this study was limited to the City of Williston and the immediate surrounding county in North Dakota because Williston is the largest community and sits at the epicenter of the Bakken. In addition, despite the potential to affect mitigation strategies used by local communities, how states use tax surcharges or oil extraction taxes was not a focus of this thesis. Many of the aforementioned social and geopolitical impacts would have required interviews and personal data outside the scope of this research.

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<sup>26</sup> “USGS Release: 3 to 4.3 Billion Barrels of Technically Recoverable Oil Assessed in North Dakota and Montana’s Bakken Formation—25 Times More Than 1995 Estimate—(4/10/2008 2:25:36 PM),” accessed October 10, 2016, <https://archive.usgs.gov/archive/sites/www.usgs.gov/newsroom/article.asp-ID=1911.html>.

<sup>27</sup> “Williston City North Dakota QuickFacts from the U.S. Census Bureau,” accessed March 29, 2016, <http://www.census.gov/quickfacts/table/PST045215/3886220,00>.

## **E. INSTRUMENTATION (DATA AND EVIDENCE)**

Inspection and violation data, processing or disposing of fracking waste information, seismic history, and data on water resource quality and consumption provided the detail needed for the analysis of environmental impact. A picture of the impact of fracking on the water sources emerged from water usage permits from the State of North Dakota Water Commission. Data on past environmental spills and fines demonstrated the frequency and magnitude of the spills associated with fracking. Data derived from monitoring sites in North Dakota, where most waste-water disposal occurs through deep well injection, enabled the evaluation of water quality and air quality. Historical seismic data throughout the Bakken verified the association of fracking with seismic activity.

City and state budgets, building permits and construction valuation reports, census data, cost of living data, aviation boarding reports, job service reports and crime figures constituted the instrument of the analysis of socioeconomic impact. City budgets identified infrastructure improvements, increased debt resulting from staffing increases, expansion of water or sewer, and increased taxes. Census data reflected changes in population, demographics, and the housing market. Data on employment rates, housing expenses, sales tax, and property taxes provided insight necessary to determine any changes in the cost of living. The FBI database facilitated an analysis of crime data and possible trends that may well accompany the associated social changes.

## **F. INTENDED OUTPUT**

The aim of this thesis was to provide governance recommendations for communities seeking to prevent, prepare, or mitigate the risks associated with fracking, in particular, or any boom-and-bust industry. Suggestions offered focus on how rural communities can better understand and decrease risks and how they can implement sound policy and regulations to preserve their natural resources and limit the societal impacts that accompany rapid growth scenarios. The information in this thesis may also help policy makers and decision makers to frame the discussion around the local impacts to communities.

## **G. PREVIEW OF CHAPTERS**

Chapter II contains a review of the current literature on fracking and its effects on the environment and the socioeconomics of a community. As of 2016, literature dealing with fracking in the Bakken region was in an emergent state; therefore, examining any trends as the data becomes available is crucial.

Chapter III offers a discussion of the case study research used to analyze the information. Data were evaluated to match patterns, build explanation, and analyze a time series to strengthen the argument of causation.

Chapter IV presents the data from a detailed discussion of the Bakken and the impacts of oil production on the environment and the socioeconomic of the area. The chapter includes a discussion of known emerging environmental concerns regarding air and water quality issues in the region and the environmental impact of water consumption in the Bakken appears. Another focus of Chapter IV is the social and economic variables associated with the boom and bust of oil production. Also appearing in Chapter IV is a description of the impacts upon the community of Williston, North Dakota, in terms of population migration, housing, infrastructure improvements, government budgets, tax burdens, crime rates, employment rates, and income levels. The Williston community provides the framework for the analysis of trends in Chapter V.

Chapter V covers commonalties identified in communities undertaking fracking and highlights findings about unintended impacts to provide a basis for the formulation of recommendations for communities.

Chapter VI provides recommendations to serve as the foundation for policy created from best practices. Prepared and proactive community leaders are crucial in the long-term prognosis of a community potentially impacted by fracking. This chapter offers recommendation and preparations that can mitigate the risk local communities may face.

## II. LITERATURE REVIEW

The short- and long-term effects of unconventional oil extraction, such as impacts on the environment, the socioeconomic changes in communities, and the risks associated with product transportation, were the subjects of ongoing research at the time of this writing. This research, however, has stalled for the following reasons. Some of the chemical processes are proprietary, the process takes place several hundred feet underground, and the process has not been in existence long enough for communities to experience or for researchers to study impacts longitudinally.<sup>28</sup> The literature indicates that the better prepared a community is for the influx of workers, the transportation of hazardous products, increased housing demands, planning and zoning activities, pressure on the infrastructure, and socioeconomic instability, the less detrimental the impacts will be.

### A. ENVIRONMENTAL IMPACTS

Advancements in hydraulic fracturing and horizontal boring have increased the feasibility of shale oil extraction. More complicated and expensive than conventional extraction, this process requires additional technology.<sup>29</sup> Thus, the fracking process, studied by both proponents and opponents, has caused controversy. Some researchers who have studied the fracking process *have published articles detailing common environmental issues*.<sup>30</sup> In addition, the New York State Department of Health,

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<sup>28</sup> Simona L. Perry, “Environmental Reviews and Case Studies: Addressing the Societal Costs of Unconventional Oil and Gas Exploration and Production: A Framework for Evaluating Short-Term, Future, and Cumulative Risks and Uncertainties of Hydrofracking,” *Environmental Practice* 14, no. 4 (December 2012): 352, doi: 10.1017/S1466046612000336.

<sup>29</sup> Murray and Hansen, “Peak Oil and Energy Independence,” 245.

<sup>30</sup> Paul C. Stern, Thomas Webler, and Mitchell J. Small, “Understanding the Risks of Unconventional Shale Gas Development,” *Environmental Science & Technology* 48, no. 15 (August 5, 2014): 8287–8288, doi: 10.1021/es502459b; Katherine E. Konschnik and Mark K. Boling, “Shale Gas Development: A Smart Regulation Framework,” *Environmental Science & Technology* 48, no. 15 (August 5, 2014): 8404–8416, doi: 10.1021/es405377u; Robert B. Jackson et al., “The Environmental Costs and Benefits of Fracking,” *Annual Review of Environment and Resources* 39, no. 1 (October 17, 2014): 327–362, doi: 10.1146/annurev-environ-031113-144051.

Congressional Research Service (CRS), and GAO have released reports detailing the effects on the environment and public health associated with fracking.<sup>31</sup>

The oil extraction process is directly connected to the environment, which poses a significant risk to the environment, as well as to public health.<sup>32</sup> Researchers have concurred that the fracking process poses a risk to air quality, water consumption, and water quality, and has induced seismic activity.<sup>33</sup> The GAO has reported that because long-term environmental and public health risks have not been documented, all risks are still unknown;<sup>34</sup> therefore, additional research is needed to provide more direction for local governments to reduce these risks.

The oil and gas found in shale, sandstone, and the coal bed is called unconventional oil. It differs from conventional oil sources that are found in deep, porous rock, and thus, flow freely; in unconventional oil production the oil and gas are trapped in the rock formation and do not flow freely.<sup>35</sup> To extract the oil and gas in rock formations, operators use a process called hydraulic fracturing, or fracking (see Figure 3).

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<sup>31</sup> Howard Zucker, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development* (Albany, NY: New York Department of Health, 2014); Michael Ratner and Mary Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions* (CRS Report No. R43148) (Washington, DC: Congressional Research Service, 2014), <http://www.pennyhill.com/jmsfile/seller/docs/R43148.pdf>; United States Government Accountability Office, *Unconventional Oil and Gas Production: Opportunities and Challenges of Oil Shale Development* (GAO-12-740T) (Washington, DC: United States Government Accountability Office, 2012).

<sup>32</sup> United States Government Accountability Office, *Unconventional Oil and Gas Production: Opportunities and Challenges of Oil Shale Development*.

<sup>33</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 33–52.

<sup>34</sup> *Ibid.*, 32.

<sup>35</sup> *Ibid.*, 5.



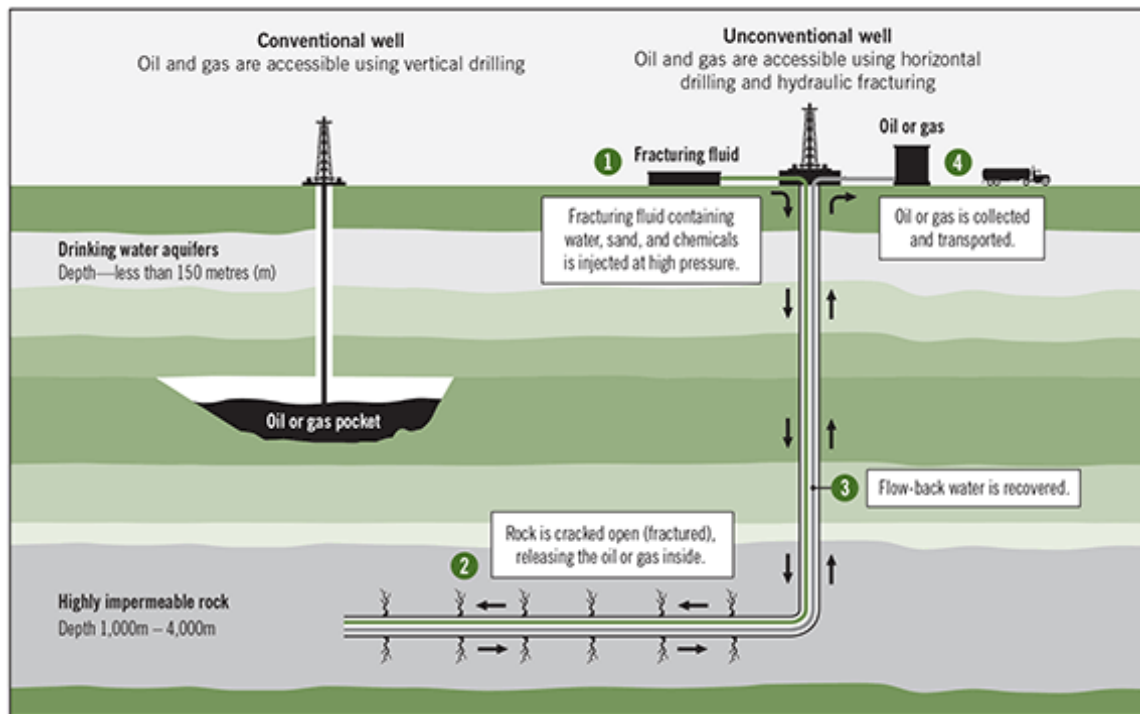


Figure 3. An Example of a Conventional and Unconventional Wells.<sup>36</sup>

The process of fracking requires multiple steps to produce a successful well. The first step—to identify a suitable source that will produce oil—starts with an operator conducting seismic testing by hitting the ground hard with a thumper mounted on a truck and measuring the energy as it bounces within the subsurface.<sup>37</sup> This measurement helps determine the characteristics of the formation. If the location appears favorable, the operator negotiates with the land owner for mineral rights to drill for oil or gas, obtaining permits from the North Dakota Industrial Commission: Oil and Gas Division (NDIC: Oil and Gas), which has authority to regulate and permit the oil and gas production in the state.<sup>38</sup>

<sup>36</sup> Source: “2012 Fall Report of the Commissioner of the Environment and Sustainable Development, Chapter 5—Environmental Petitions,” [http://www.oag-bvg.gc.ca/internet/English/parl\\_cesd\\_201212\\_05\\_e\\_37714.html](http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201212_05_e_37714.html).

<sup>37</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 7.

<sup>38</sup> “Welcome to the North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division, Home Page,” accessed August 31, 2016, <https://www.dmr.nd.gov/oilgas/>.

Generally, the operation then moves into the development phase, which includes construction of a well pad, drilling, well construction, and hydraulic fracturing of the rock.<sup>39</sup>

First, the site must be prepared by removing surface vegetation and leveling the ground. The pad site must be made large enough to allow for frequent truck and heavy machinery traffic. Infrastructure including roads, tanks, impoundment ponds, piping, and the drill rig must also be constructed.<sup>40</sup> Next, equipment and the additives (chemicals), sand, and water that will be mixed together and injected during the fracking process must be transported to the site. Impoundment ponds or pits must be constructed and lined for the storage of fracturing fluids, commonly referred to as produced water or brine.<sup>41</sup>

The third phase is a multistep process, during which a wellbore is drilled through a series of vertical and horizontal holes. At multiple and varying depths, the drill bit is removed and a casing is inserted and cemented for cohesion with the rock.<sup>42</sup> This step is critical because it prevents fugitive gas from moving along the bore casing to other ground sources or the surface. To monitor the pressure and also prevent the uncontrolled release of oil or gas, a blowout preventer is installed.<sup>43</sup> As the wellbore is drilled, a lubricant known as a drilling fluid is injected to flush the drilling debris away from the bit to the surface. This mixture of rock debris and drilling fluid is collected in the impoundment pond.<sup>44</sup>

After the vertical portion of the wellbore is complete, cement is again injected to seal the casing, followed by horizontal drilling through the shale.<sup>45</sup> Horizontal well bores can extend 2,000 to 6,000 feet from the vertical wellbore.<sup>46</sup> During the drilling process,

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<sup>39</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 7–8.

<sup>40</sup> *Ibid.*, 8.

<sup>41</sup> *Ibid.*

<sup>42</sup> *Ibid.*

<sup>43</sup> *Ibid.*

<sup>44</sup> *Ibid.*

<sup>45</sup> *Ibid.*

<sup>46</sup> *Ibid.*, 9.

natural gas is commonly released from the wellbore and either vented or flared. If the gas is flared, it is ignited and consumed. If the gas is vented, it is released directly into the atmosphere. The process of venting natural gas has been found to contribute to the production of smog and can contain toxic volatile organic compounds (VOCs).<sup>47</sup> Flaring produces carbon monoxide and contributes to greenhouse gas production but decreases the impact from VOCs.<sup>48</sup>

The fourth phase is the fracking process (see Figure 4). To prepare the well for stimulation, the operator must insert a metal pipe with holes, designed to release fracturing fluid and propanant into the rock fractures. Fracturing fluid, water, and sand (known as propanant) are injected under pressure to fracture the rock and allow for the release of oil and gas. Fracturing fluids can differ in chemical makeup and are adjusted to the rock conditions.<sup>49</sup> Once the pressure fractures the rock formation, the propanant keeps the fracture open.<sup>50</sup> During the fracking process, some of the fracturing fluid, along with water that is naturally found in the rock formation, returns to the surface. That fluid is commonly referred to as produced water, flowback, or brine.<sup>51</sup> Until it can be transported for treatment, recycled to be used at a different drill site, or disposed of by injection into wells, the produced water is collected at the site pad in impoundment ponds.<sup>52</sup> Once the well initially produces, the equipment and infrastructure used for the drilling and fracturing process are removed and relocated.<sup>53</sup>

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<sup>47</sup> Ratner and Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, 9.

<sup>48</sup> Ibid.

<sup>49</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 11.

<sup>50</sup> Ibid., 12.

<sup>51</sup> Ibid.

<sup>52</sup> Ibid.

<sup>53</sup> Ibid., 13.

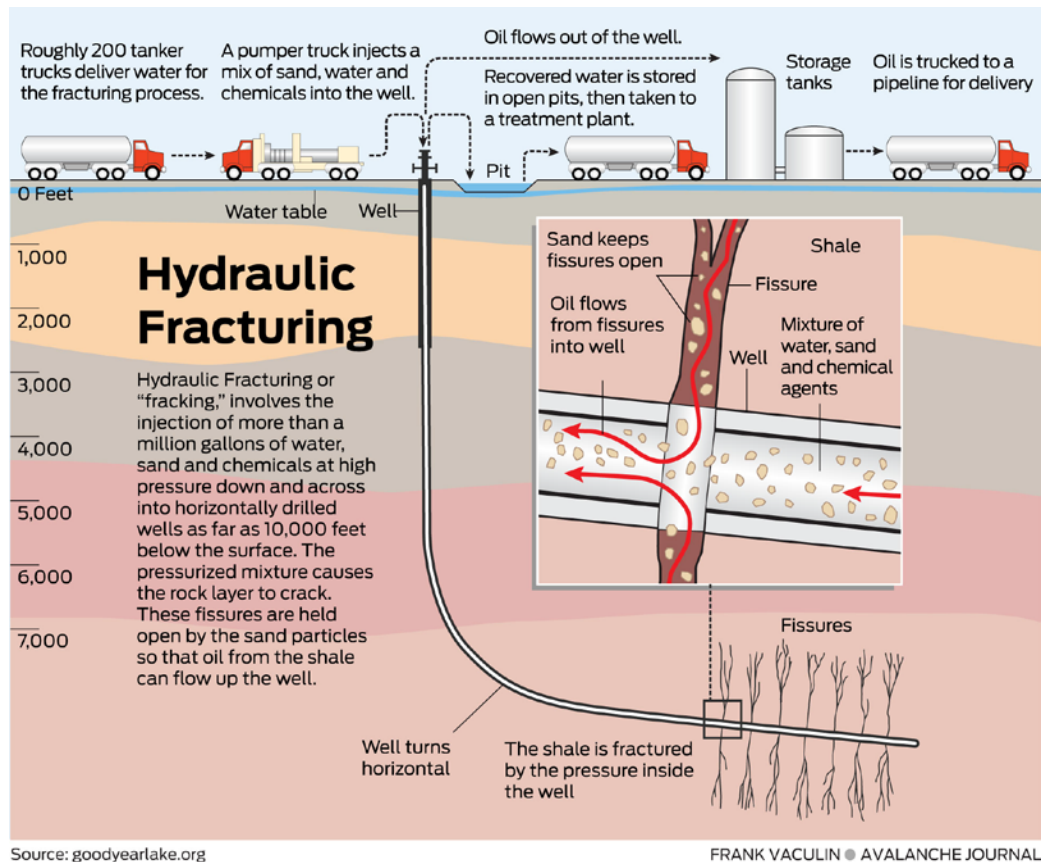


Figure 4. The Hydraulic Fracturing Process.<sup>54</sup>

## 1. Air Quality

Researchers have agreed that shale oil extraction affects air quality. A multistage oil extraction can require between 320 and 1,365 truckloads to transport the necessary water, chemicals, sand, and heavy equipment to drill a well.<sup>55</sup> This increased truck traffic decreases air quality because of its release of nitrogen oxides and particulate matter.<sup>56</sup> “There can also be long-term regional increases in air pollutants from oil shale processing and the generation of additional electricity to power oil shale development operations. Pollutants, such as dust, nitrogen oxides, and sulfur dioxide, can contribute to the

<sup>54</sup> Source: “Squeezing the Shale,” accessed August 28, 2016, [http://lubbockonline.com/Squeezing\\_Shale](http://lubbockonline.com/Squeezing_Shale).

<sup>55</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 13.

<sup>56</sup> Ibid.

formation of regional haze.”<sup>57</sup> The flaring, or burning off of natural gas, from the shale oil, also affects air quality.<sup>58</sup> The flaring process produces carbon dioxide, methane, and other volatile compounds that contribute to greenhouse gas emissions.<sup>59</sup> According to an Environmental Protection Agency (EPA) report, “Natural gas completions involving hydraulic fracturing vent substantially more natural gas, approximately 230 times more, than natural gas completions not involving hydraulic fracturing.”<sup>60</sup>

Numerous researchers and the CRS have expressed concerns that air emissions from open-air water containment pits can allow the release of volatile organic compounds (VOCs) into the air.<sup>61</sup> Various levels of toxic gases, such as methane, benzene, toluene, and occasionally hydrogen sulfide, are released into the air and contain VOCs, which are known carcinogens.<sup>62</sup> According to the GAO, several serious health concerns are associated with air contaminants near the drill site.<sup>63</sup> When emission sources were combined to include drilling, fracking, and truck and power generation needs, nitrous oxide emissions at the site were estimated to have increased between 12% and 27%.<sup>64</sup> Research conducted to estimate the damage associated with shale oil extraction in

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<sup>57</sup> United States Government Accountability Office, *Unconventional Oil and Gas Production: Opportunities and Challenges of Oil Shale Development*, Highlights.

<sup>58</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 35.

<sup>59</sup> Ibid.

<sup>60</sup> U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Final New Source Performance Standards and Amendments to the National Emissions Standards for Hazardous Air Pollutants for the Oil and Natural Gas Industry* (Research Triangle Park, NC: U.S. Environmental Protection Agency, 2012), 3–6.

<sup>61</sup> Jackson et al., “The Environmental Costs and Benefits of Fracking”; Christopher W. Moore et al., “Air Impacts of Increased Natural Gas Acquisition, Processing, and Use: A Critical Review,” *Environmental Science & Technology* 48, no. 15 (August 5, 2014): 8349–8359, doi: 10.1021/es4053472; Ratner and Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, 9.

<sup>62</sup> Jackson et al., “The Environmental Costs and Benefits of Fracking,” 346–347.

<sup>63</sup> United States Government Accountability Office, *Unconventional Oil and Gas Development, Key Environmental and Public Health Requirements* (GAO-12-874) (Washington, DC: United States Government Accountability Office, 2012), 14–15.

<sup>64</sup> Moore et al., “Air Impacts of Increased Natural Gas Acquisition, Processing, and Use,” 8353.

Pennsylvania showed annual damage to be \$2.5 to \$5.5 million for the life of the well.<sup>65</sup> Pennsylvania shale oil extraction contributed to an increase of 2.60%–10% VOCs, 29%–30% nitrous oxide gases, and 35%–55% sulfur dioxide gases.<sup>66</sup>

## **2. Water Consumption**

Water consumption is another environmental and public health concern associated with fracking. Research has shown that shale oil extraction presents a risk to both surface and ground water<sup>67</sup> because of extraction, the consumption of water in the fracking process, water requiring water consumption, and water taken from surface and underground water sources.<sup>68</sup> The removal of water from lakes, streams, and rivers can jeopardize the quality of those sources subject to higher summer temperatures, which adversely affects aquatic life and wildlife habitat.<sup>69</sup> Similarly, the removal of water from shallow aquifers can deplete ground water sources and the streams and springs fed by them.<sup>70</sup> Removal from deeper aquifers has long-lasting effects because deep aquifers take a very long time to replenish.<sup>71</sup> This amount of water consumption is of great concern because the water used for fracking is permanently removed from the water cycle as a result of waste-water injection into deep rock formations.<sup>72</sup>

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<sup>65</sup> Aviva Litovitz et al., “Estimation of Regional Air-Quality Damages from Marcellus Shale Natural Gas Extraction in Pennsylvania,” *Environmental Research Letters* 8, no. 1 (January 31, 2013): 5, doi: 10.1088/1748-9326/8/1/014017.

<sup>66</sup> Moore et al., “Air Impacts of Increased Natural Gas Acquisition, Processing, and Use,” 8353.

<sup>67</sup> Jackson et al., “The Environmental Costs and Benefits of Fracking,” 478–493; B. R. Scanlon, R. C. Reedy, and J.-P. Nicot, “Comparison of Water Use for Hydraulic Fracturing for Unconventional Oil and Gas versus Conventional Oil,” *Environmental Science & Technology* 48, no. 20 (October 21, 2014): 12386–12393, doi: 10.1021/es502506v; Avner Vengosh et al., “A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States,” *Environmental Science & Technology* 48, no. 15 (August 5, 2014): 8334–8348, doi: 10.1021/es405118y; United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 37–39.

<sup>68</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 37.

<sup>69</sup> *Ibid.*, 38.

<sup>70</sup> *Ibid.*

<sup>71</sup> *Ibid.*

<sup>72</sup> *Ibid.*, 39.

Despite a sizable consumption, research has indicated that water consumption through fracking pales in comparison to conventional oil extraction and other usage as in thermoelectric power plants and agricultural irrigation.<sup>73</sup> That said, water consumption could eventually limit the growth of the shale oil industry because of a lack of the resource.<sup>74</sup> The cumulative effects of drilling in a region can negatively impact the local water supply and make the region vulnerable to drought.<sup>75</sup>

### **3. Water Quality**

The shale oil extraction process provides the potential for the underground migration of gas and chemicals that can contaminate the water of nearby drinking water wells.<sup>76</sup> When an oil well is neither properly protected nor isolated from water sources through the casing and cementing process, gas and other fluids from the extraction process can migrate into nearby drinking water aquifers.<sup>77</sup> This migration occurs through fractures that have been created or natural fractures that can be thousands of meters away.<sup>78</sup> The challenge is that research is indicative of a minimal risk of water contamination, but the risk exists. Research spanning a 25-year period in Ohio identified 185 cases of groundwater contamination, or a 0.1% occurrence rate attributed to fracking. In Texas, the rate of occurrence was lower at 0.02%.<sup>79</sup>

Water quality is also potentially impacted by the release of produced water, which contains chemicals, oil, and gases. This release can occur onsite or during

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<sup>73</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 38; Scanlon, Reedy, and Nicot, "Comparison of Water Use for Hydraulic Fracturing for Unconventional Oil and Gas versus Conventional Oil," 12392; Vengosh et al., "A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States," 8343.

<sup>74</sup> United States Government Accountability Office, *Unconventional Oil and Gas Production: Opportunities and Challenges of Oil Shale Development*, 6.

<sup>75</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 39.

<sup>76</sup> Stern, Weblar, and Small, "Understanding the Risks of Unconventional Shale Gas Development," 8287.

<sup>77</sup> Jackson et al., "The Environmental Costs and Benefits of Fracking," 341.

<sup>78</sup> Ibid.

<sup>79</sup> Ibid., 339.

transportation.<sup>80</sup> Onsite, produced water is stored in an impoundment area until a time when it can be disposed of or treated.<sup>81</sup> During storage, risks occur from tears in the storage liner and from overflows of the impoundment area.<sup>82</sup> In 2010 and 2011, melting snows in North Dakota caused overflows of impoundment areas.<sup>83</sup> If produced water is disposed of, it is taken by truck or train, and transportation is always accompanied by the risk of accidental spillage.<sup>84</sup>

#### **4. Seismic Activity**

Treatment of wastewater, or produced water, from a drilling well is potentially damaging to water treatment plants. An alternative to wastewater treatment is subsurface injection that disposes the contaminated water by injecting it back into a used well. Onsite disposal of produced water through injection can reduce the expense and risk of transporting the waste off site.<sup>85</sup> The injection disposal method has unknown long-term effects.<sup>86</sup> Seismic activity can occur from rock formations that undergo stress changes. During or soon after hydraulic fracturing, the fault line may become critically stressed;<sup>87</sup> however, they concluded that the likelihood of hydraulic fracturing-induced earthquakes

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<sup>80</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 7; Jackson et al., “The Environmental Costs and Benefits of Fracking,” 341–344; Luisa Torres, Om Prakash Yadav, and Eakalak Khan, “A Review on Risk Assessment Techniques for Hydraulic Fracturing Water and Produced Water Management Implemented in Onshore Unconventional Oil and Gas Production,” *Science of The Total Environment* 539 (January 2016): 478–93, doi: 10.1016/j.scitotenv.2015.09.030.

<sup>81</sup> Ibid.

<sup>82</sup> Ibid.

<sup>83</sup> Ibid.

<sup>84</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 39–42.

<sup>85</sup> Torres, Yadav, and Khan, “A Review on Risk Assessment Techniques for Hydraulic Fracturing Water and Produced Water Management Implemented in Onshore Unconventional Oil and Gas Production,” 491.

<sup>86</sup> Ibid.

<sup>87</sup> Richard Davies et al., “Induced Seismicity and Hydraulic Fracturing for the Recovery of Hydrocarbons,” *Marine and Petroleum Geology* 45 (August 2013): 172, doi: 10.1016/j.marpetgeo.2013.03.016.



is extremely small, and if it occurs, a small-magnitude earthquake is the probable result.<sup>88</sup>

Pennsylvania had a limited the number of wells suitable for disposal injection.<sup>89</sup> To resolve its problem, Pennsylvania found locations in Ohio that would take its contaminated produced water and inject it into wells for disposal.<sup>90</sup> From March 2011 to January 2012, twelve earthquakes occurred in Ohio, ranging from 2.1 to 4.0 on the Richter scale. In March 2012, the Ohio Department of Natural Resources acknowledged “a compelling argument” that injection of produced water induced the seismic activity.<sup>91</sup> This acknowledgement led the Ohio Governor to put a moratorium on injection in the Youngtown area.<sup>92</sup> A conflict between the two states quickly developed.<sup>93</sup>

## **B. SOCIOECONOMIC CHALLENGES**

### **1. Population In-Migration**

Oil extraction and production typically coincide with rapid economic growth and a population influx.<sup>94</sup> This phenomenon, commonly known as a “boomtown” or a

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<sup>88</sup> Ibid., 183.

<sup>89</sup> Barry G. Rabe and Christopher Borick, “Conventional Politics for Unconventional Drilling? Lessons from Pennsylvania’s Early Move into Fracking Policy Development: Conventional Politics for Unconventional Drilling,” *Review of Policy Research* 30, no. 3 (May 2013): 337, doi: 10.1111/ropr.12018.

<sup>90</sup> Ibid.

<sup>91</sup> United States Government Accountability Office, *Unconventional Oil and Gas Development, Key Environmental and Public Health Requirements*, 59.

<sup>92</sup> Ibid.

<sup>93</sup> Rabe and Borick, “Conventional Politics for Unconventional Drilling?” 337; Barry G. Rabe, “Shale Play Politics: The Intergovernmental Odyssey of American Shale Governance,” *Environmental Science & Technology* 48, no. 15 (August 5, 2014): 8375, doi: 10.1021/es4051132.

<sup>94</sup> Kai A. Schafft, Yetkin Borlu, and Leland Glenna, “The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity,” *Rural Sociology* 78, no. 2 (June 2013): 143.

“boom-and-bust cycle,” has impacted communities.<sup>95</sup> Recent boomtown studies have centered on the tremendous population growth resulting from the fracking of shale oil. This growth has mainly occurred in rural communities, the nature of which has made them more vulnerable to rapid population contractions as the oil price or production decreases.<sup>96</sup>

The preboom population experiences negative social consequences because of the influx of workers from other areas,<sup>97</sup> some of which include “rising divorce rates, prostitution, alcoholism and drug abuse, childhood stress, and mental health issues.”<sup>98</sup> New workers have diverse backgrounds, bringing with them different cultural and social norms that may well clash with those in an already established community. Long-term residents face frustration and the insecurity of not knowing new neighbors. Additional cultural and social norms bring a shift in values. For long-term residents, all the change creates a perception that everything is about money. In many ways, original residents feel nostalgic about their old lifestyle and regret the chaos that oil production has brought to their community.<sup>99</sup>

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<sup>95</sup> Jeffrey B. Jacquet, “Review of Risks to Communities from Shale Energy Development,” *Environmental Science & Technology* 48, no. 15 (August 5, 2014): 8322–23, doi: 10.1021/es404647x; Shawn Dalton, *Discussion Paper—Potential Socioeconomic Effects of Unconventional Oil and Gas Development in Nova Scotia Communities* (Sydney, Nova Scotia, Canada: Cape Breton University, 2014), 8–10, <https://www.google.com/search?q=socioeconomical+impact+of+unconventional+oil+exploration&ie=utf-8&oe=utf-8>; Schafft, Borlu, and Glenna, “The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity,” 144–146; Jessica Crowe et al., “Differences in Public Perceptions and Leaders’ Perceptions on Hydraulic Fracturing and Shale Development,” *Sociological Perspectives* 58, no. 3 (2015): 445.

<sup>96</sup> Audrey Putz, Alex Finken, and Gary A. Goreham, *Sustainability in Natural Resource-Dependent Regions That Experienced Boom-Bust-Recovery Cycles: Lessons Learned from a Review of the Literature*, Center for Community Vitality Working Paper (Fargo, ND: North Dakota State University, 2011), 14, <http://www.visionwestnd.com/pdf/Boom-bust%20communities.pdf>.

<sup>97</sup> Schafft, Borlu, and Glenna, “The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity,” 144–145; Dalton, *Discussion Paper—Potential Socioeconomic Effects of Unconventional Oil and Gas Development in Nova Scotia Communities*, 9.

<sup>98</sup> Schafft, Borlu, and Glenna, “The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity,” 144.

<sup>99</sup> Shelby Bohnenkamp et al., *Concerns of the North Dakota Bakken Oil Counties: Extension Service and Other Organizations’ Program Responses to These Concerns* (Fargo, ND: Center for Community Vitality, NDSU Extension Service, 2011), 7–8, [http://www.visionwestnd.com/pdf/bakken\\_needs\\_report.pdf](http://www.visionwestnd.com/pdf/bakken_needs_report.pdf)

## 2. Housing

During the extraction and development phases, activity is more intense and requires numerous truck drivers, mechanics, heavy equipment operators, and rig workers among others.<sup>100</sup> Numerous researchers have found that those who follow shale oil work are primarily young males who have no ties to the community, which causes a shift in community demographics.<sup>101</sup> From July 1, 2010, to July 1, 2014, the U.S. Census Bureau showed an estimated increase of 9.9% in the population of North Dakota, attributed to an over 43% population growth in Williams County. Williston, North Dakota is located in Williams County and is the epicenter of the Bakken oil production.<sup>102</sup> Compared to the national unemployment rate of 7.4% and a job growth rate of .32% in July 2013, Williston had an unemployment rate of 0.07% and a job growth rate of 32.09%.<sup>103</sup> That population increase exacerbated the already tight housing market in North Dakota.<sup>104</sup>

As the shale oil boom started in North Dakota, its housing costs skyrocketed along with the cost of living.<sup>105</sup> The same type of housing crunch doubled or tripled rent prices during the early stages of the Marcellus development, a shale oil formation primarily a natural gas producer located in Pennsylvania.<sup>106</sup> In addition, increasing housing costs displaced those on fixed incomes.<sup>107</sup> People in communities without rent

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<sup>100</sup> KLJ, Inc., *2014–2019 North Dakota Oil and Gas Industry Impact Study* (Bismarck, ND: KLJ, Inc., 2014), 30–31.

<sup>101</sup> Rick Ruddell et al., “Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties,” *Western Criminology Review* 15, no. 1 (April 2014): 3; Carol L. Cwiak et al., *The New Normal: The Direct and Indirect Impacts of Oil Drilling and Production on the Emergency Management Function in North Dakota* (Fargo, ND: North Dakota State University, 2015), 23, [http://www.ndsu.edu/fileadmin/emgt/FINALThe\\_New\\_Normal\\_January\\_2015\\_a.pdf](http://www.ndsu.edu/fileadmin/emgt/FINALThe_New_Normal_January_2015_a.pdf); KLJ, Inc., *2014–2019 North Dakota Oil and Gas Industry Impact Study*, 38.

<sup>102</sup> “American FactFinder, Cumulative Estimates of Resident Population Change and Rankings: April 1, 2010 to July 1, 2014—State -- County/County Equivalent 2014 Population Estimates,” accessed November 8, 2015, [http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP\\_2014\\_PEP\\_CUMCHG.ST05&prodType=table](http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2014_PEP_CUMCHG.ST05&prodType=table).

<sup>103</sup> Jacquet, “Review of Risks to Communities from Shale Energy Development,” 8322.

<sup>104</sup> Cwiak et al., *The New Normal*, 23–25.

<sup>105</sup> Bohnenkamp et al., *Concerns of the North Dakota Bakken Oil Counties*, 8.

<sup>106</sup> Schafft, Borlu, and Glenna, “The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity,” 150.

<sup>107</sup> *Ibid.*; Crowe et al., “Differences in Public Perceptions and Leaders’ Perceptions on Hydraulic Fracturing and Shale Development,” 445.

control witnessed their rent increase from \$300 to \$900 per month, and others paid \$100 per night for the use of a bedroom in a house.<sup>108</sup> Renters able to find apartments paid rates comparable to that for apartments in New York City or Washington, DC.<sup>109</sup> Those most adversely impacted were renters, single parents, and those on fixed incomes who did not enjoy wealth from the oil production.<sup>110</sup>

Temporary crew housing facilities, called “man camps,”<sup>111</sup> required the issuing of numerous new permits because of the housing crunch. Williston, North Dakota, permitted 17 temporary facilities, totaling 1,966 beds.<sup>112</sup> To meet its housing demand, the city expanded from 4,571 acres in 2010 to 12,994 acres in 2014.<sup>113</sup> In 2007, the city issued 339 commercial and residential permits, valued at \$42 million. In 2013, that increased to 1,665 residential permits valued at \$353 million.<sup>114</sup>

As shale oil extraction flourished in North Dakota, employee housing costs were typically provided by the oil companies.<sup>115</sup> Some companies paid close to \$40 million a year for room and board for 1,000 workers, typically at \$500 per day for an out-of-town worker. Perks, such as room cleaning, catered meals of beef, shrimp, or lobster every day, and big screen TVs with all the channels were used to help recruit workers to these mostly rural areas. As the price of oil dropped, the man camps turned into ghost towns and the free benefits disappeared. At that point, most oil companies were withdrawing from the housing business.<sup>116</sup>

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<sup>108</sup> Bohnenkamp et al., *Concerns of the North Dakota Bakken Oil Counties*, 8.

<sup>109</sup> Putz, Finken, and Goreham, *Sustainability in Natural Resource-Dependent Regions That Experienced Boom-Bust-Recovery Cycles*, 19.

<sup>110</sup> Schafft, Borlu, and Glenna, “The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity,” 150.

<sup>111</sup> Eric Killelea, “Boomtown USA,” *Planning* 80, no. 8 (September 8, 2014): 26.

<sup>112</sup> *Ibid.*, 27.

<sup>113</sup> *Ibid.*

<sup>114</sup> *Ibid.*

<sup>115</sup> David Wethe and Kelly Gilblom, “Oil’s New Boomtowns Head toward Bust,” *Business Week*, no. 4423 (April 20, 2015): 27–28.

<sup>116</sup> *Ibid.*

### 3. Infrastructure

Williston's growth came at considerable financial cost to its residents. Its budget increased from \$25 million in 2009 to \$196.2 million in 2014, with \$142 million earmarked for debt services for bonds sold to finance infrastructure improvements.<sup>117</sup> As of 2014, over 93% of sales tax revenue coming into the city was designated to repay city debt,<sup>118</sup> which placed a tremendous burden on local residents because the risk of busting increases as oil prices drop. Compounding the financial burden, the fear of moving too quickly and being saddled with a substantial infrastructure debt can lead to resistance. In Williston, North Dakota, the last boom-and-bust cycle burdened the community with debt totaling \$28 million.<sup>119</sup> Those memories have caused Williston residents some apprehension about risking so much in the future.<sup>120</sup>

Some communities have charged the oil companies a road consumption cost for projected road damage and reconstruction costs.<sup>121</sup> The cost can be based on the type of road, the round-trip travel distance from the well site to the transfer location, and the number of trucks the well requires.<sup>122</sup> The estimated cost for a one-way 20-mile trip is between \$13,000 and \$23,000 per well with the variance based on the number of truckloads deemed heavy or light.<sup>123</sup>

An estimated 70% of oil production in North Dakota's Bakken region requires transfer to rail terminals or pipelines via trucks;<sup>124</sup> furthermore, the oil extraction process requires many truckloads of heavy equipment and materials, which can damage local and

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<sup>117</sup> Killelea, "Boomtown USA," 28.

<sup>118</sup> Killelea, "Boomtown USA," 28.

<sup>119</sup> *Ibid.*, 26.

<sup>120</sup> *Ibid.*

<sup>121</sup> Shmuel Abramzon et al., "Estimating the Consumptive Use Costs of Shale Natural Gas Extraction on Pennsylvania Roadways," *Journal of Infrastructure Systems* 20, no. 3 (September 2014): 6, doi: 10.1061/(ASCE)IS.1943-555X.0000203.

<sup>122</sup> *Ibid.*, 4.

<sup>123</sup> *Ibid.*, 5.

<sup>124</sup> Cwiak et al., *The New Normal*, 31.

state roads.<sup>125</sup> According to the North Dakota Department of Transportation (NDDOT), the movement of an oil rig requires approximately 100 truckloads of equipment, 50 of which require special permits for overweight or overlength.<sup>126</sup> A number of factors affect potential damage, such as truck weight, the type and number of truck axles, the continuity of the traffic flow pattern, and the road's design.<sup>127</sup>

Roads in the Bakken region were intended for rural usage, not oil transportation. Those roads have been subjected to constant overweight and overlength hauling of products and equipment that negatively affect their life span.<sup>128</sup> According to the NDDOT's *TransAction III: North Dakota's Statewide Strategic Transportation Plan*, roads deteriorated as a result of consistent traffic, necessitating repairs and creating a domino effect. Road closures for repair were followed by traffic rerouting followed by delays.<sup>129</sup> Increased usage has extended beyond the Bakken region; the entire state of North Dakota has seen a spike in vehicular movement as a result of the oil boom. Prior to the latest oil boom, the number of vehicle miles traveled (VMT) showed a typical increase of 3% or 4% per year on the 106,600 miles of roadways in the Bakken. Between 2010 and 2011, VMT increased by more than 6% statewide with a 26% increase in statewide truck traffic that can be attributed to the increase road traffic need to produce oil.<sup>130</sup>

Usage increases roadway maintenance and repair costs,<sup>131</sup> which can be exacerbated by high labor and material costs. North Dakota construction supplies and

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<sup>125</sup> Abramzon et al., "Estimating the Consumptive Use Costs of Shale Natural Gas Extraction on Pennsylvania Roadways," 2.

<sup>126</sup> North Dakota Department of Transportation, "TransAction III: North Dakota's Statewide Strategic Transportation Plan, North Dakota Drilling and Production Statistics," 19, 2012, <https://www.dmr.nd.gov/oilgas/stats/statisticsvw.asp>.

<sup>127</sup> Abramzon et al., "Estimating the Consumptive Use Costs of Shale Natural Gas Extraction on Pennsylvania Roadways," 2.

<sup>128</sup> Ibid.

<sup>129</sup> North Dakota Department of Transportation, "TransAction III: North Dakota's Statewide Strategic Transportation Plan," 19.

<sup>130</sup> Ibid.

<sup>131</sup> Bohnenkamp et al., *Concerns of the North Dakota Bakken Oil Counties*, 10.

workers have been at a premium since the latest boom, resulting in increased cost.<sup>132</sup> A road overlay project that would have cost \$80,000 before the boom increased to \$115,000, marking a 90% increase in the North Dakota Highway Department Construction Cost Index.<sup>133</sup>

As a solution, assessing the cost of the roadway to the oil company could be a recoverable cost for the community. Local governments are provided more flexibility in financing such large expenditures. Another option to decrease road stress is to reduce the number of permits issued for overweight or overlength trucks. A third option is to build roadways to accommodate heavier loads and traffic volumes.<sup>134</sup> All three options have positive and negative effects and require careful consideration by decision makers.<sup>135</sup>

#### **4. Crime**

Researchers have found a correlation between the rapid population growth that coincides with an oil boom and an increase in crime rate and antisocial behavior.<sup>136</sup> A decrease in quality of life associated with traffic congestion and a fear of drunk drivers have been identified as contributing factors.<sup>137</sup> Many of the law enforcement agencies located in affected communities have experienced an increase in demand for their services, stretching thin their personnel. Compounding the need for additional resources has been increased employee burnout and recruitment challenges because of an expected heavy work demand.<sup>138</sup>

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<sup>132</sup> North Dakota Department of Transportation, “TransAction III: North Dakota’s Statewide Strategic Transportation Plan,” 20.

<sup>133</sup> Ibid.

<sup>134</sup> Abramzon et al., “Estimating the Consumptive Use Costs of Shale Natural Gas Extraction on Pennsylvania Roadways,” 6.

<sup>135</sup> Ibid.

<sup>136</sup> Ruddell et al., “Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties,” 3; Putz, Finken, and Goreham, *Sustainability in Natural Resource-Dependent Regions That Experienced Boom-Bust-Recovery Cycle*, 18; Cwiak et al., *The New Normal*, 44.

<sup>137</sup> Ruddell et al., “Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties,” 4.

<sup>138</sup> Ibid.

The violent crime index from 2005 to 2011 identified a 32% increase in the violent crime rate in oil-producing counties of the Bakken area. Comparatively, nonoil-producing counties observed a 5% increase during that same time period.<sup>139</sup> Since 2011, the number of defendants charged in federal court in the Bakken area nearly doubled with a 31% increase in 2013 alone.<sup>140</sup> From 2005 to 2011, law enforcement agencies in the 22 oil-producing counties in Montana and North Dakota saw an 82% increase in call volume.<sup>141</sup>

Traffic-related accidents have also increased in oil-producing counties. The 33 oil-producing counties recorded a 57.5% increase in vehicular crashes from 2006 to 2011.<sup>142</sup> During that time, North Dakota saw an 81% increase in traffic fatalities, and Montana's oil-producing counties experienced a 47% increase. Despite a lack of awareness of statistics, community leaders, residents, and law enforcement officers in the oil-producing counties echoed the sentiment about increased risk on the roads.<sup>143</sup>

Data points were difficult to analyze because of missing or incomplete data from sparsely populated counties.<sup>144</sup> One limiting factor in the crime data was a lack of identification of all crime through the Uniform Crime Rate Report (UCR); some nonviolent data was considered part of the crime matrix. Crime rates fluctuated as community and decision makers adjusted to meet the challenges.<sup>145</sup> Once the work force stabilized and workers established more permanence in the community, an observable impact on the crime rate ensued.

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<sup>139</sup> Ibid., 5.

<sup>140</sup> Ibid.

<sup>141</sup> Ruddell et al., "Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties," 5.

<sup>142</sup> Ibid.

<sup>143</sup> Ibid.

<sup>144</sup> Ibid., 10.

<sup>145</sup> Ibid.



## **C. CONCLUSION**

Based on the literature, the complexities associated with fracking are evident. At issue is the impact of those complexities. Environmentally, the impact on water consumption, water quality, air quality, and the initiation of earthquakes is of concern. Although concerns have been expressed, the literature has been inconsistent with regard to the degree of those environmental impacts. Many subtleties in the socioeconomic issues closely compare to the historic boom-and-bust cycles associated with mineral exploration. Issues have included a large population influx, a housing shortage, income disparity, community infrastructure needs, and crime. All issues, environmental and socioeconomic, must be examined holistically instead of as single attributing factors to understand their significance best and obtain clarity.

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### III. RESEARCH METHODOLOGY

Where is additional research most needed to provide the critical knowledge for improved understanding and management of shale gas [or oil] technology, its risks, and its governance? Given the rapidly evolving technology and deployment of unconventional shale gas drilling, an assessment of the current state of knowledge of its risks and governance elements . . . is critically needed.

—Paul Stern, Thomas Webler, and Mitchell Small  
“Understanding the Risks of Unconventional Shale Gas Development”

#### A. INTRODUCTION

The profitability and other economic benefits of increased domestic oil production should not supersede the unintended consequences of fracking. Since hydraulic fracking of shale oil is an emerging technology, evaluating, acknowledging, and sharing all side effects and risks associated with the process are critical. Oil exploration and production have commonly been associated with a boom-and-bust phenomenon.<sup>146</sup> Leaders of any community where shale formation may be discovered should have an understanding of all consequences, so they can be best prepared with plans, policies, and regulations. Significant pressure has been placed on those community leaders and decision makers to create effective and prudent policies because shale oil exploration has been associated with environmental and socioeconomic concerns.

#### B. RESEARCH METHODOLOGY

This thesis explored unintended consequences as they played out in the largest shale oil formation in the United States—Bakken–Three Forks<sup>147</sup> formation in North Dakota. Three analytical assessments were conducted as a case study of the Bakken–Three Forks, in which patterns associated with the effects of fracking were examined to

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<sup>146</sup> Putz, Finken, and Goreham, *Sustainability in Natural Resource-Dependent Regions That Experienced Boom-Bust-Recovery Cycles*, 11.

<sup>147</sup> The Three Forks formation extends above and below the Bakken Formation, but the two formations incorporate the area focus of the thesis.

build an explanation of how and why effects have occurred and examine the events on a timeline of pre-boom and the situation in 2016. As the framework for the analysis, three of Robert Yin's five recommended analytical techniques were used for case studies.<sup>148</sup> Yin suggested that those analytical techniques yield powerful and compelling case studies; thus, use pattern matching, explanation building, and time-series analysis were chosen to evaluate impacts in the Bakken–Three Forks region.<sup>149</sup>

### **C. DATA COLLECTION**

Data collection included researching the shale oil production process and the known impacts to the environment and community. Scholarly articles, books, and journals along with official reports, government websites, public records, newspapers, and open source information served as data sources. Choosing the case study of the Bakken–Three Forks was based on two factors, the Bakken–Three Forks Formation is the largest shale oil formation in the United States and the rural and sparsely populated communities in the Bakken–Three Forks are vulnerable to the boom-and-bust phenomenon. To answer the primary research question—what are the effects of unconventional shale oil exploration?—and the ancillary question—how can communities prepare for, prevent, or mitigate the unintended consequences associated with shale oil exploration—embedded variables and associated data for analysis were evaluated.

### **D. DATA ANALYSIS**

First, the data according to Yin's suggested analytical process were analyzed and the variables and their corresponding data were assessed to determine whether emerging patterns could be identified and compared to the literature and previous research. Second, the data were evaluated to build an effective explanation of how or why the effects associated with unconventional oil exploration are present in the Bakken. Finally, the data over time was also evaluated. All three analytical methods facilitated the assessment

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<sup>148</sup> Yin, *Case Study Research*, 126.

<sup>149</sup> *Ibid.*, 135–145.

of the impacts to produce recommendations for clearer policy and governance guidance for local communities.

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#### IV. CASE STUDY OF THE BAKKEN

Advances in horizontal drilling for gas exploration can be equated with greater control and estimation. Thousands of feet below the surface, operators can accurately control drilling.<sup>150</sup> The control has allowed the pinpointing of oil and gas trapped in the striations or layers of shale, tight sandstone, and coalbeds. Figure 5 shows the location of the Bakken–Three Forks Formation in the Williston basin, mapped by the United States Geologic Survey (USGS) and comprising an area that spans western North Dakota, eastern Montana, South Dakota, and the Canadian provinces of Saskatchewan and Manitoba.<sup>151</sup> After conducting a thorough assessment of that area, the USGS estimated that it contained “7.4 billion barrels of oil, 6.7 trillion cubic feet of associated/dissolved natural gas, and .053 billion barrels of natural gas liquids.”<sup>152</sup>

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<sup>150</sup> United States Government Accountability Office, *Unconventional Oil and Gas Development, Key Environmental and Public Health Requirements*, 1.

<sup>151</sup> Stephanie B. Gaswirth et al., *Assessment of Undiscovered Oil Resources in the Bakken and Three Forks Formations, Williston Basin Province, Montana, North Dakota, and South Dakota, 2013, National Assessment of Oil and Gas Fact Sheet* (Reston, VA: U.S. Department of the Interior and U. S. Geological Survey 2013), 1, <http://pubs.usgs.gov/fs/2013/3013/fs2013-3013.pdf>.

<sup>152</sup> Ibid.

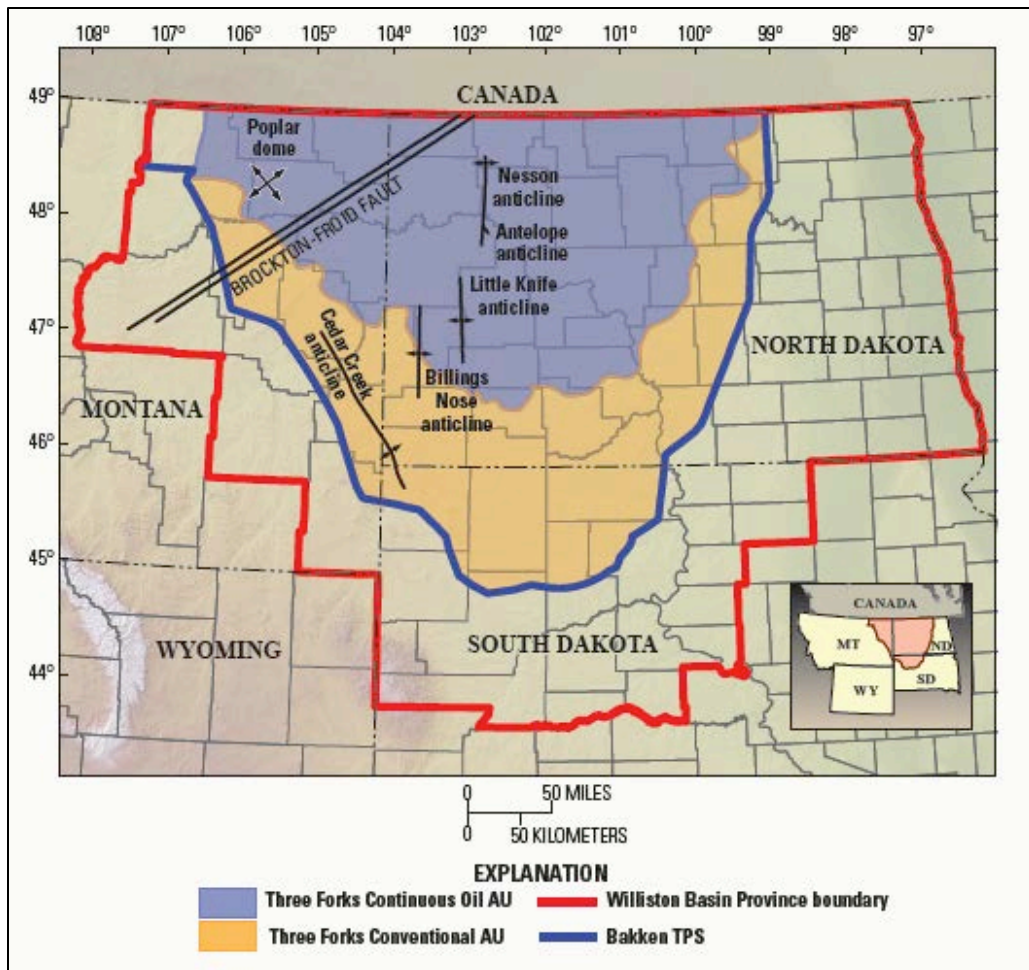


Figure 5. Map of the Bakken–Three Forks Formation.<sup>153</sup>

North Dakota has a history of booms and busts in oil production.<sup>154</sup> In the 1960s, the “gold rush” of North Dakota oil created a hope that the state’s oil production would compare to that of Texas. In the 1980s, a spike in oil prices made production profitable with a peak in 1984. The most recent boom was fostered by 3D modeling that identified potential deposits that could be tapped using advanced drilling techniques.<sup>155</sup> Although the previous oil booms in the 1960s and 1980s saw oil production increases, those booms

<sup>153</sup> Source: Gaswirth et al., *Assessment of Undiscovered Oil Resources in the Bakken and Three Forks Formations, Williston Basin Province, Montana, North Dakota, and South Dakota*, 2013, *National Assessment of Oil and Gas Fact Sheet*.

<sup>154</sup> “A Brief History of North Dakota Oil Production, North Dakota’s Oil Bust in the 1980s,” June 2, 2011, <https://northdakotaoil.wordpress.com/2011/06/02/north-dakota%e2%80%99s-oil-bust-in-the-1980s/>.

<sup>155</sup> Ibid.



pale in comparison to the recent increase in oil production as a result of fracking (see Figure 6). From the 1990s to mid-2000s, oil production was fairly stable at 300,000 million barrels per year with rig counts typically hovering around the low teens.<sup>156</sup> In 2005, the number of rigs increased as did oil production. In 2014, the price of oil dropped, as did rig counts in North Dakota; however, the efficiency of North Dakota's oil production increased to a record 432,286,156 barrels in 2015.<sup>157</sup>

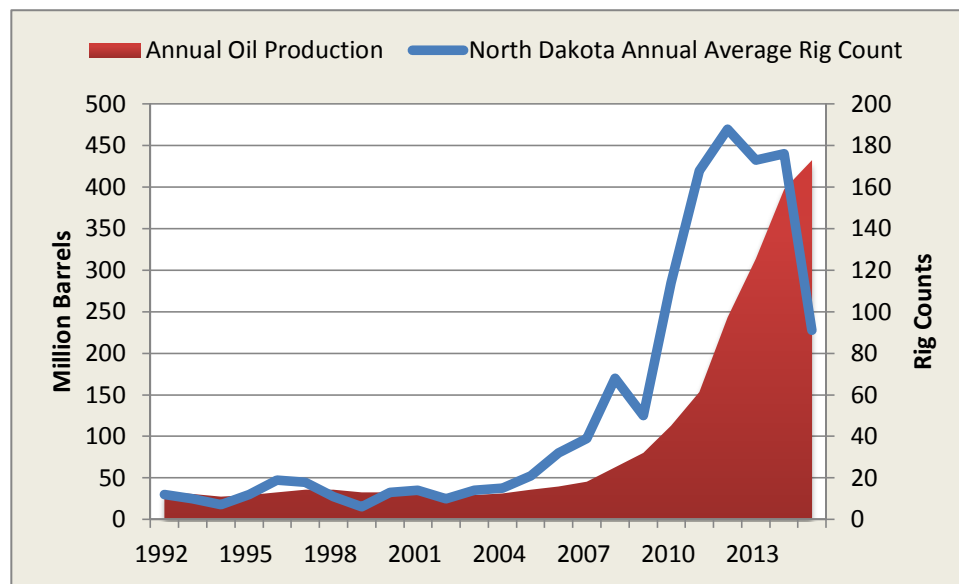


Figure 6. North Dakota Oil History.<sup>158</sup>

Long-term low oil prices significantly impact the number of new wells drilled, which becomes problematic when production levels of current wells decrease. Those effects were apparent in the beginning of 2016. In April 2016, oil production had its

<sup>156</sup> Industrial Commission of North Dakota: Oil and Gas Division, *Oil in North Dakota\_2015 Production Statistics* (Bismarck, ND: Industrial Commission of North Dakota, n.d.), XIV.

<sup>157</sup> Industrial Commission of North Dakota: Oil and Gas Division, *Oil in North Dakota\_2015 Production Statistics*, XI.

<sup>158</sup> Adapted from “North America Rig Count,” accessed October 14, 2016, <http://www.bakerhughes.com/>; “North Dakota Drilling and Production Statistics,” accessed August 31, 2016, <https://www.dmr.nd.gov/oilgas/stats/statisticsvw.asp>.

biggest daily drop ever, a 6% decrease, producing 1.04 million barrels per day.<sup>159</sup> Department of Mineral Resources Director Lynn Helms “attributed the 70,400-barrel-per-day drop to the ongoing oil industry slowdown, but said weather and other factors made the decline ‘abnormally high.’”<sup>160</sup> He said, “The month of April also had 15 days that were too windy for crews to complete wells. . . . Spring road restrictions also were in effect in April, which severely limited the travel of heavy trucks and equipment needed for fracking and other well operations.”<sup>161</sup>

For the first time since 2008, no oil rigs existed in Williams County, which includes the boomtown of Williston (see Figure 7).<sup>162</sup> The green rigs indicate wells producing on August 22, 2016, and the red lines are the oil field locations

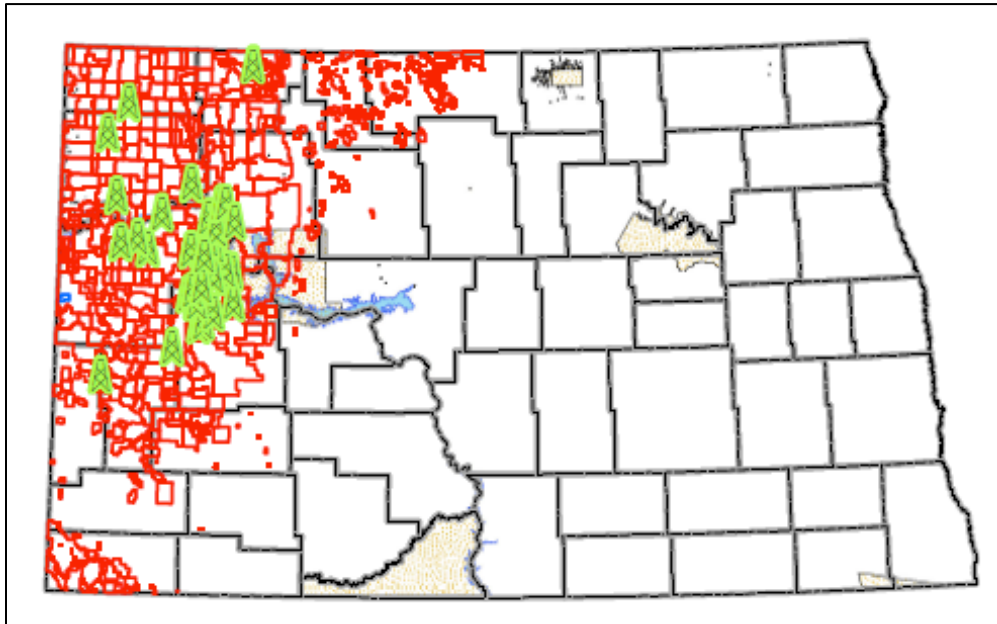


Figure 7. North Dakota Oil Rig and Oil Field Locations.<sup>163</sup>

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<sup>159</sup> Amy Dalrymple, “ND Sees Big Drop in Oil Production; Zero Rigs in Williams County,” June 15, 2016, INFORUM, <http://www.inforum.com/news/4055223-nd-sees-big-drop-oil-production-zero-rigs-williams-county>.

<sup>160</sup> Ibid.

<sup>161</sup> Dalrymple, “ND Sees Big Drop in Oil Production; Zero Rigs in Williams County.”

<sup>162</sup> Ibid. There were no oil rigs for the week of June 12, 2016 in Williams County, “Williams County, which includes the oil hub of Williston, dropped to zero drilling rigs this week for the first time since October 2008.”

The center of the current North Dakota boom lies in four counties: McKenzie, Mountrail, Dunn, and Williams (see Figure 8). Due to their high output of oil, those four counties were examined in this study for environmental impacts. Since the mid-2000s, when fracking and horizontal drilling made shale oil production more profitable, production levels dramatically increased in those counties.

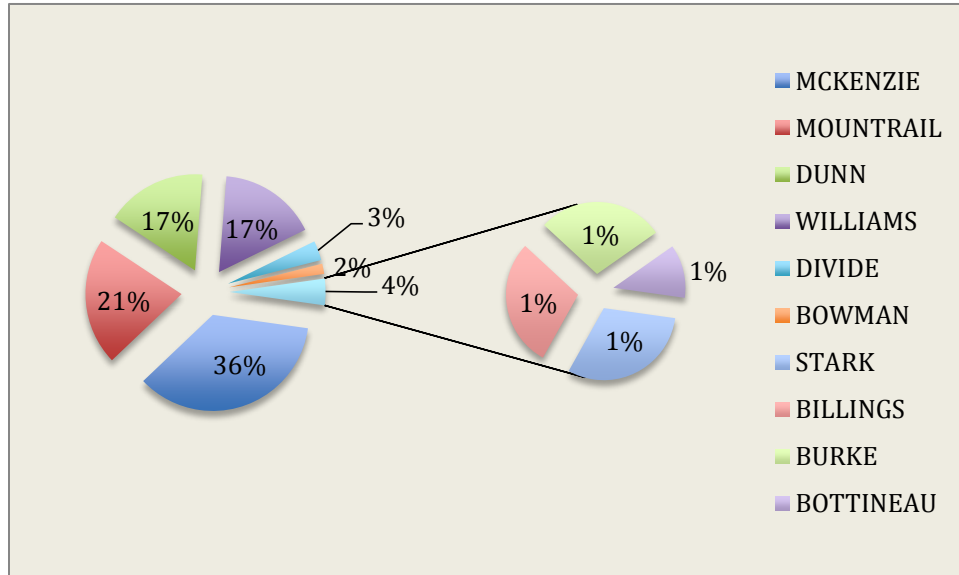


Figure 8. Percentages of Oil Produced in the Top 10 North Dakota Counties for 2015.<sup>164</sup>

At one point, over 30 million barrels were produced each month by the four counties alone (see Figure 9).<sup>165</sup> As of June 2016, the leading producing county was McKenzie (41% of North Dakota oil), followed by Mountrail (22%), Dunn (19%), and Williams (18%).<sup>166</sup>

<sup>163</sup> Source: “Welcome to the North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division, Home Page.”

<sup>164</sup> Adapted from “Welcome to the North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division, Home Page.”

<sup>165</sup> “North Dakota Drilling and Production Statistics.”

<sup>166</sup> Ibid.

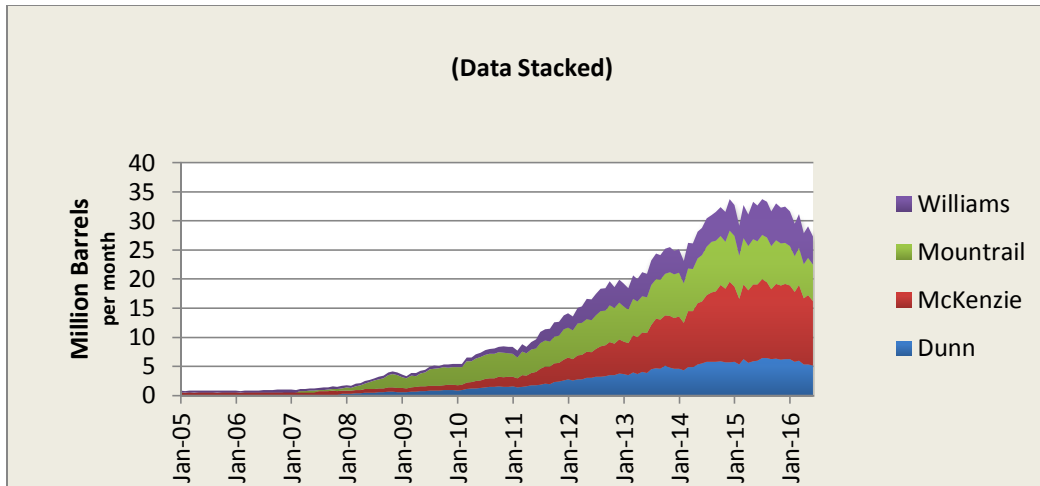


Figure 9. Oil Production Trends in the Top Four North Dakota Counties.<sup>167</sup>

The dramatic potential for oil extraction in North Dakota has stimulated not only oil production but also population growth, an increase in personal income, and the creation of jobs (see Figure 10).<sup>168</sup> Those benefits have come with some unintended consequences, such as damage to the environment and dramatic shifts in the socioeconomics of the region. Those unintended consequences are the focus of this case study.

<sup>167</sup> Adapted from “Welcome to the North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division, Home Page.”

<sup>168</sup> “Bakken Shale Map: An Investor’s Introduction to the Formation—Investing Daily,” accessed August 31, 2016, <http://www.investingdaily.com/15159/bakken-shale-map-an-investors-introduction-to-the-formation/>.

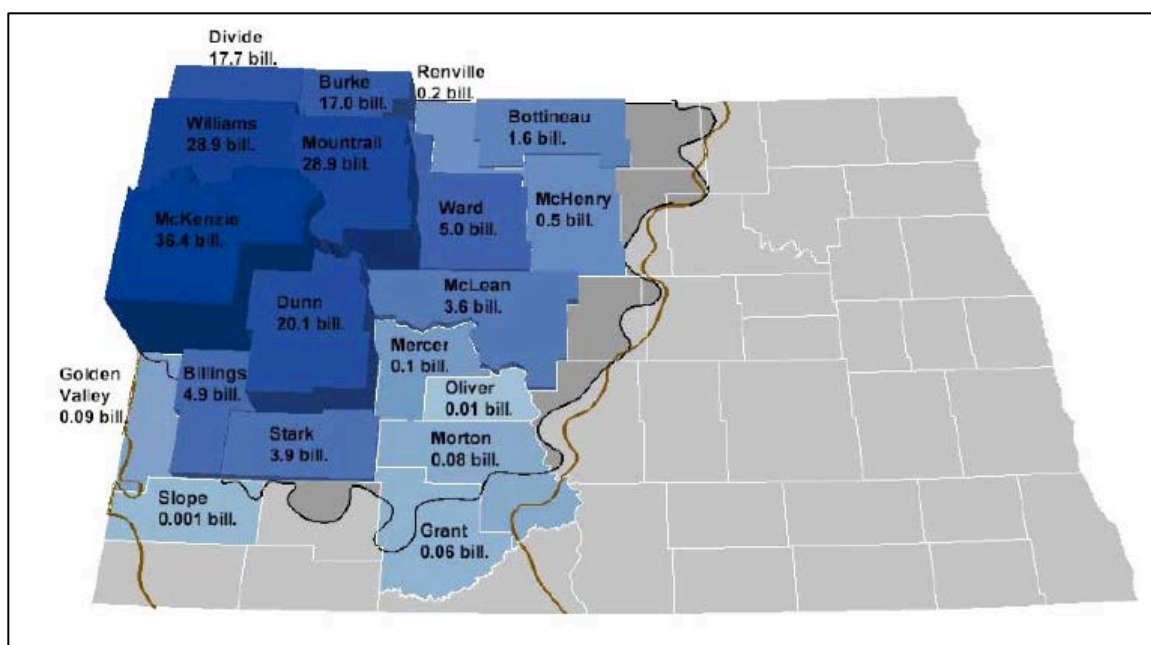


Figure 10. Potential Oil Existing in Western North Dakota Portion of Bakken/Three Forks.<sup>169</sup>

#### A. CASE STUDY (ENVIRONMENTAL)

Oil production, either by conventional or unconventional methods, has the potential to seriously impact the environment; however, because hydraulic fracturing of shale is still a relatively new process, and because it occurs hundreds of feet below the earth's surface, many of the environmental concerns are not fully known.<sup>170</sup> To minimize the potential impacts of unconventional oil extraction, various safety measures, mitigation strategies, and best practices can be applied. These, however, require public policy action to ensure that safeguards are implemented.<sup>171</sup> To improve appreciation of these impacts, the effects of fracking on water consumption, water quality, air quality, and seismic activity were examined.

<sup>169</sup> Source: "Bakken Shale Map: An Investor's Introduction to the Formation—Investing Daily."

<sup>170</sup> United States Government Accountability Office, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, 32.

<sup>171</sup> Ratner and Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, 7.

## 1. The Region's Water Sources

Oil exploration, in particular the tremendous amount of unconventional exploration, has led to concerns about the use of and impact on water sources. Controversy driven by a rush to production has clouded understanding of whether fracking causes groundwater pollution if spills contaminate surface water or eventually leech into groundwater and whether consuming large amounts of water during the fracking process wastes resources.<sup>172</sup> The issue is complex and the long-term effects are still relatively unknown. This research explored these issues by examining whether those risks are present in the Bakken–Three Forks area.

Understanding the impact of fracking on the Bakken–Three Forks water sources requires an examination of the region's aquifer and its two water basins. In 2011, the USGS began an examination of the aquifer system that spans North Dakota, South Dakota, Montana, and Wyoming in the United States and the provinces of Manitoba and Saskatchewan in Canada. The report was published in 2014.<sup>173</sup> The two water basins in the oil-producing area—Williston and Powder River—have seen a rapid expansion in fracking.<sup>174</sup> The Williston Basin is primarily in North Dakota and Montana with small portions in South Dakota, Manitoba, and Saskatchewan; the Powder River basin lies primarily in Wyoming and Montana.<sup>175</sup> Since the Powder River Basin is not located in North Dakota, only the impacts to the Williston basin were studied.

Knowledge of the replenishment of the region's aquifer is instrumental in understanding whether the quantity of water is in jeopardy. Replenishing an aquifer can occur in three ways: through precipitation that infiltrates groundwater sources,<sup>176</sup> via

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<sup>172</sup> Vengosh et al., “A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States,” 8334; Andrew J. Long et al., *Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada* (Reston, VA: U.S. Geological Survey, 2014), 1.

<sup>173</sup> Long et al., *Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada*, 1.

<sup>174</sup> *Ibid.*

<sup>175</sup> *Ibid.*, 2.

<sup>176</sup> *Ibid.*, 12.

surface water, rivers and streams, migrating to groundwater sources,<sup>177</sup> and by means of runoff from the irrigation of crops, which can infiltrate groundwater sources.<sup>178</sup> The Williston Basin typically receives between 11 and 22 inches of annual precipitation, recharging only 26% of what the aquifer accepts.<sup>179</sup> Replenishment through surface water is estimated at 71%,<sup>180</sup> and only 2% of the basin's replacement has occurred as a result of irrigation.<sup>181</sup> These data indicate how critical surface water has been to the basin's groundwater supply. In addition, should precipitation decrease to a level causing rivers and streams to dry up, replenishment of groundwater sources would be hampered. In summary, the Williston Basin relies heavily on its rivers and streams for groundwater replacement.

## **2. Water Consumption**

Increased municipal water usage from the Williston Basin has decreased groundwater resources. From 2005 to 2015, industrial permits accounted for 10% of all the permitted water use. The remaining 90% was used for irrigation, municipal water, livestock, and the production of hydraulic electricity (see Figure 11).<sup>182</sup>

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<sup>177</sup> Long et al., *Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada*, 12.

<sup>178</sup> *Ibid.*

<sup>179</sup> *Ibid.*, 13.

<sup>180</sup> *Ibid.*

<sup>181</sup> *Ibid.*, 15.

<sup>182</sup> "Water Use Report," accessed August 14, 2016, [http://www.swc.nd.gov/info\\_edu/map\\_data\\_resources/waterpermits/waterusereport.php](http://www.swc.nd.gov/info_edu/map_data_resources/waterpermits/waterusereport.php).

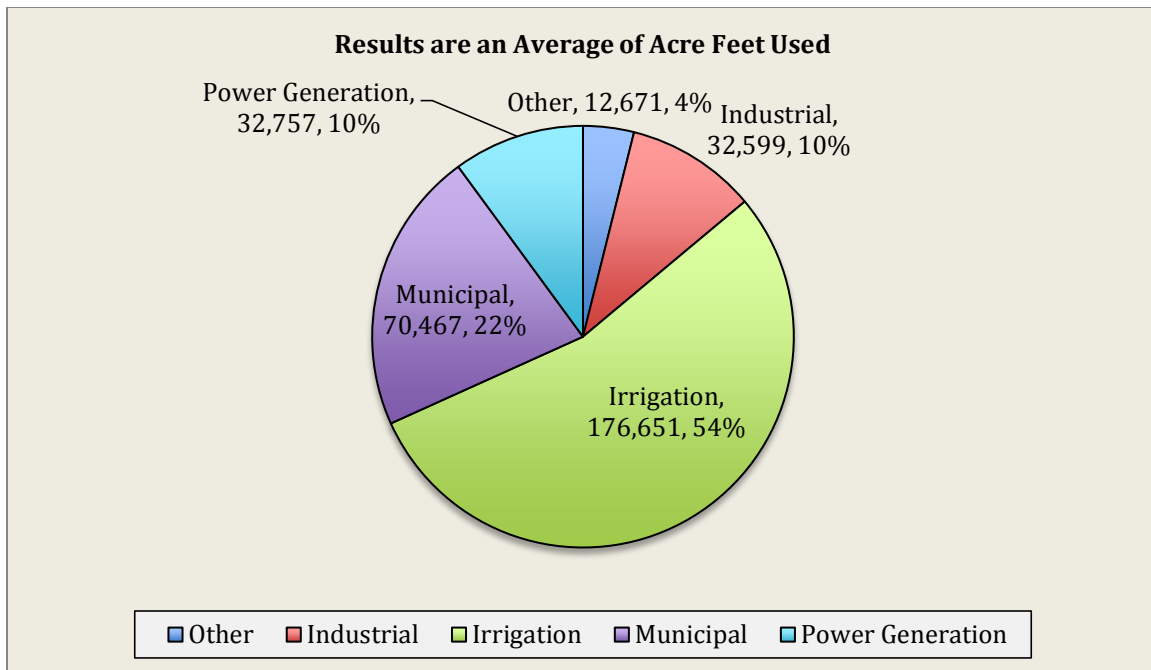


Figure 11. North Dakota Water Use Permits from 2005–2015.<sup>183</sup>

The USGS found that groundwater levels in the area were constant until roughly 2000. Since then, those levels have declined as a result of municipal wells constantly removing water and changing the groundwater pressure.<sup>184</sup> The majority, or 96%, of groundwater discharge ran to rivers and streams via natural springs; the remaining 4% of the discharge was used for all the permitted purposes.<sup>185</sup> An examination of aquifer recharge via stream infiltration, compared with the discharge, indicated a deficiency of roughly 6%. According to the USGS, “the total estimated stream infiltration is 3,260 ft<sup>3</sup>/s, and groundwater discharge to streams is 4,420 ft<sup>3</sup>/s, which are 71 and 97 percent of total recharge and total discharge, respectively.”<sup>186</sup> The result has been a relentless drawing down of the aquifer brought about by higher demand.

<sup>183</sup> Adapted from “Water Use Report” and North Dakota Water Commission database of permits issued.

<sup>184</sup> Long et al., *Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada*, 26.

<sup>185</sup> *Ibid.*, 14.

<sup>186</sup> *Ibid.*, 19.



Water consumption as part of the fracking process has been a noteworthy concern because it removes large quantities of fresh water from the aquifer and surface water sources as part of the process. An estimated 133,000 gallons per well are needed during drilling to make the wellbore.<sup>187</sup> Once the metal pipes are inserted, an additional 1.5 to 4 million gallons are needed for cementing the casings, hydraulic fracturing, oil recovery and refining, and diluting the produced (flowback) water.<sup>188</sup> In roughly 10% of the wells, an additional 526,000 gallons are needed to dilute heavy concentrations of salt brine in the produced oil, which can affect the functioning of the well.<sup>189</sup> Since 2008, more than 5,000 wells have been drilled.<sup>190</sup> Based on those estimates, between  $8,165 \times 10^6$  and  $20,665 \times 10^6$  gallons of water have been used for North Dakota fracking, representing 63,585 acre-feet of water. Although some of that water may have been processed through a treatment plant or recycled, so as not to be removed from the water cycle, a significant amount of it has been forever lost to the water supply system.

In the effort to track water consumption in North Dakota, its state engineer and the North Dakota Water Commission manage water resource usage and permits.<sup>191</sup> Table 1 shows yearly water use reported by industry, which covers commercial businesses, such as manufacturing, mining, and processing.<sup>192</sup> The amounts of water used for industrial purposes can be compared to the amount of water used by fracking to determine the burden that fracking puts on water availability.

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<sup>187</sup> W. M. Schuh, *Water Appropriation Requirements, Current Water Use, & Water Availability for Energy Industries in North Dakota—A 2010 Summary* (Bismarck, ND: North Dakota Water Commission, 2010), ES-6, [www.swc.nd.gov/info\\_edu/reports\\_and.../pdfs/wr.../wr49\\_report.pdf](http://www.swc.nd.gov/info_edu/reports_and.../pdfs/wr.../wr49_report.pdf).

<sup>188</sup> Ibid.

<sup>189</sup> Ibid.; Long et al., *Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada*, 2.

<sup>190</sup> P. B. McMahon et al., “Quality and Age of Shallow Groundwater in the Bakken Formation Production Area, Williston Basin, Montana and North Dakota,” *Groundwater* 53, no. S1 (April 2015): 81, doi: 10.1111/gwat.12296.

<sup>191</sup> “Water Use Report.”

<sup>192</sup> Ibid.

Table 1. Annual Water Permits Issued in North Dakota.<sup>193</sup>

Water Usage for Industrial Water Permits						
Total			Groundwater		Surface Water	
Year	*Acre Feet	% CNG	*Acre Feet	% CNG	*Acre Feet	% CNG
2005	23,004		11,419		11,586	
2006	24,386	6	11,811	3	12,576	9
2007	25,348	4	12,339	4	13,008	3
2008	27,436	8	13,994	13	13,442	3
2009	26,911	-2	13,910	-1	13,002	-3
2010	31,070	15	15,848	14	15,223	17
2011	35,737	15	18,942	20	16,794	10
2012	39,862	12	21,392	13	18,470	10
2013	38,410	-4	19,735	-8	18,675	1
2014	45,489	18	21,809	11	23,680	27
2015	40,932	-10	18,953	-13	21,979	-7

\*Acre-foot - the volume of water that will cover an area of one acre to a depth of one foot (325,851 gallons).

A dramatic increase in industrial water usage has occurred in the top four oil-producing counties: McKenzie, Williams, Mountrail, and Dunn (see Figure 12). The data were obtained from the North Dakota Water Commission and tabulated for analysis.<sup>194</sup> They show the combined water usage, as well as a positive correlation between fracking and water usage. Prior to the oil boom, industrial water permits were negligible in the top oil-producing counties of Mountrail, Dunn, McKenzie, and William using 0.1, 105, 305, and 670 acre-feet, respectively, in 2005.<sup>195</sup> As the dramatic increase in fracking occurred, so did a corresponding increase in water consumption, peaking in 2014 with the combined four counties consuming 20,353 acre-feet (6,632,045,403 gallons) in one year.<sup>196</sup>

<sup>193</sup> Adapted from “Water Use Report” and North Dakota Water Commission database of permits issued.

<sup>194</sup> Ibid.

<sup>195</sup> Ibid.

<sup>196</sup> Ibid.

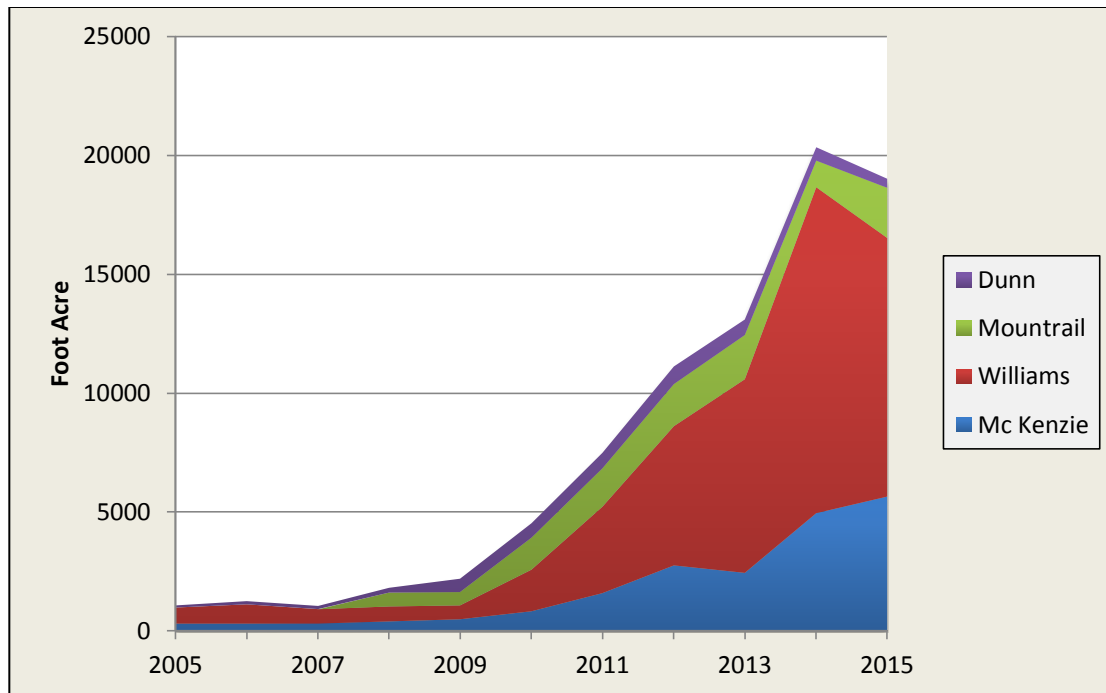


Figure 12. Combined Water Usage of the Top Four Oil-Producing Counties.<sup>197</sup>

Although the quantity of water used for industrial purposes is roughly half the quantity used for irrigation or municipal purposes, industry is a large consumer and takes water out of the water cycle without replenishing the aquifer (Figure 9). An estimated 5% to 40% of water injected for fracking actually returns to the surface in the produced water (flowback), and 60% to 95% is lost into the ground formation.<sup>198</sup> For comparison, water used for irrigation returns to the aquifer, even in small amounts. Typically, water used by the municipality can be treated in a water treatment facility and returned to the water cycle. For the water lost in the ground formation, the risk of water contamination at the fracking site is believed to vary across the country.<sup>199</sup> Although the likelihood that

<sup>197</sup> Adapted from “Water Use Report” and North Dakota Water Commission database of permits issued.

<sup>198</sup> Tanya J. Gallegos et al., “Hydraulic Fracturing Water Use Variability in the United States and Potential Environmental Implications,” *Water Resources Research* 51, no. 7 (July 1, 2015): 5844, doi: 10.1002/2015WR017278.

<sup>199</sup> *Ibid.*, 5843–5833.

injected water could reach drinking water aquifers in some areas in slim, the risk warrants concern because of a possible delay in the detection of contaminates.<sup>200</sup>

### **3. Handling of Produced Water**

A challenging consequence of the process of oil exploration, both conventional and unconventional, is the handling of produced water, which consists of some of the water injected in addition to water from the formation. It can have high levels of salinity from total dissolved solids (TDS)<sup>201</sup> and contains a mixture of “salts, oil and grease, natural organic and inorganic compounds, chemical additives, and natural radioactive materials from the formation.”<sup>202</sup> Of additional concern to North Dakota is that TDS levels in the Bakken, which are higher than in other U.S. hydraulic fracturing sites,<sup>203</sup> can reach 632,689 mg/L. According to the North Dakota Department of Health, levels in excess of 500 mg/L result in unusable water unless treated. In North Dakota, very few hydraulic fracturing sources contain less than 500 mg/L.<sup>204</sup> In addition, the salinity of the flowback water, also known as brine, has salt levels that pose a significant problem to the environment if spilled.<sup>205</sup>

Although the existence of toxins from produced water is a concern, perhaps a greater concern is the federal policies pertaining to hydraulic fracturing that apply only when the process occurs on federal land; states have authority over regulation, compliance checks, and enforcement of oil and gas production on land that is not federal, raising concerns over safe practices.<sup>206</sup> Federal policies designed to protect the public

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<sup>200</sup> Gallegos et al., “Hydraulic Fracturing Water Use Variability in the United States and Potential Environmental Implications,” 5844.

<sup>201</sup> Torres, Yadav, and Khan, “A Review on Risk Assessment Techniques for Hydraulic Fracturing Water and Produced Water Management Implemented in Onshore Unconventional Oil and Gas Production,” 482.

<sup>202</sup> Ibid.

<sup>203</sup> Ibid.

<sup>204</sup> Ibid.; Carl Anderson, “How Mineral Affect the Water Supplies,” North Dakota Department of Health, January 26, 2015, 1, <https://www.ndhealth.gov/wq/gw/pubs/mineral.htm>.

<sup>205</sup> Todd M. Preston and Tara L. Chesley-Preston, “Risk Assessment of Brine Contamination to Aquatic Resources from Energy Development in Glacial Drift Deposits: Williston Basin, USA,” *Science of the Total Environment* 508 (March 2015): 534, doi: 10.1016/j.scitotenv.2014.11.054.

<sup>206</sup> Ibid.

water supply have no influence because the hydraulic fracturing process is exempt from following the Safe Water Drinking Act (SWDA) except for the disallowance of injecting diesel as a result of the 2005 Energy Policy Act.<sup>207</sup>

At sites in the United States, produced water has been handled in various ways. In some locations, produced water has the potential for reuse if it is held in evaporation ponds for refracturing in the most proximal well or moved to another location for drilling.<sup>208</sup> In North Dakota, produced water is typically stored in tanks instead of evaporation ponds for eventual injection into disposal wells.<sup>209</sup> The North Dakota Industrial Commission has prohibited the use of evaporation ponds and open pits for storage of drill fluid from wells deeper than 1,520 m. In addition, ponds must be cleaned up within one year of drilling completion.<sup>210</sup>

A second handling option is to treat produced water at a private industrial facility, municipal water treatment plant, or publicly owned treatment facility;<sup>211</sup> however, treatment facilities are not often equipped to handle produced water properly, resulting in the possible contamination of surface waters.<sup>212</sup>

A third handling option is called deep well injection, which involves injecting the fluid back into the ground. In 2015, a record 441 million barrels of brine were injected into the Bakken, a sharp increase from 136 million barrels in 2010 and 70 million barrels

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<sup>207</sup> Preston and Chesley-Preston, "Risk Assessment of Brine Contamination to Aquatic Resources from Energy Development in Glacial Drift Deposits: Williston Basin, USA," 534.

<sup>208</sup> Ibid.; Vengosh et al., "A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States," 8341; Torres, Yadav, and Khan, "A Review on Risk Assessment Techniques for Hydraulic Fracturing Water and Produced Water Management Implemented in Onshore Unconventional Oil and Gas Production," 483.

<sup>209</sup> Torres, Yadav, and Khan, "A Review on Risk Assessment Techniques for Hydraulic Fracturing Water and Produced Water Management Implemented in Onshore Unconventional Oil and Gas Production," 483.

<sup>210</sup> Ibid.

<sup>211</sup> Vengosh et al., "A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States," 8341.

<sup>212</sup> Ibid.

in 2000.<sup>213</sup> In North Dakota, the Department of Mineral Resources: Oil and Gas Division allows only the injection of brines, produced water, and other fluids from oil and gas production in Class II wells, which are constructed to meet Environmental Protection Agency (EPA) classifications.<sup>214</sup> Research has identified two major risks associated with deep well wastewater injection, potential contamination of groundwater, and induced seismic activity.

#### **4. Contamination of Groundwater**

Water samples from 30 different wells in the Bakken showed no evidence that oil and gas production have affected the groundwater.<sup>215</sup> In 2015, researchers reported evidence of brine contamination at a few well sites but were unable to connect the contamination to oil production.<sup>216</sup> Thick geologic layers separate the shallow water source from the deeper shale where wastewater is injected, and no evidence of connectivity between them has been found.<sup>217</sup> Although geology varies with each formation, the risk of water contamination from the deep well injection used in North Dakota appears to have been reduced.

#### **5. Induced Seismic Activity**

Since 2010, evidence has supported a strong correlation between deep well injection and seismic activity in the central and eastern United States.<sup>218</sup> Researchers have linked wastewater disposal injection with earthquakes, which has raised serious

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<sup>213</sup> Lauren Donovan, “Earthquakes Not North Dakota’s Problem,” *Bismarck Tribune*, May 31, 2016, [http://bismarcktribune.com/news/state-and-regional/earthquakes-not-north-dakota-s-problem/article\\_c2485671-d783-5e05-b5b5-fff2572ba80d.html](http://bismarcktribune.com/news/state-and-regional/earthquakes-not-north-dakota-s-problem/article_c2485671-d783-5e05-b5b5-fff2572ba80d.html).

<sup>214</sup> Carl Anderson and Derek Kannenberg, “Underground Injection Control Program,” North Dakota Department of Health, January 26, 2015, 2, <http://www.ndhealth.gov/WQ/GW/uic.htm>.

<sup>215</sup> McMahon et al., “Quality and Age of Shallow Groundwater in the Bakken Formation Production Area, Williston Basin, Montana and North Dakota,” 91.

<sup>216</sup> *Ibid.*, 84–87.

<sup>217</sup> *Ibid.*, 87.

<sup>218</sup> Mark D. Petersen et al., *2016 One-Year Seismic Hazard Forecast for the Central and Eastern United States from Induced and Natural Earthquakes*, USGS Numbered Series, Open-File Report (Reston, VA: U.S. Geological Survey, 2016), 2, <http://pubs.er.usgs.gov/publication/ofr20161035>.

concerns with this disposal procedure.<sup>219</sup> The USGS determined the difficulty in linking the occurrence of an earthquake to wastewater injection because of the geo-spatial and temporal variables of earthquakes. Understanding of the differences between natural and induced earthquakes, as well as the typically unknown length and depth of causative faults remains inadequate.<sup>220</sup>

A 2013 report indicated that

at the time of publication, the NRC had identified 156 global locations where induced seismicity was suspected to be caused by energy technologies (during the last ~80+ years). Geothermal projects and reservoir impoundment projects (e.g., dam construction and hydroelectric power generation) accounted for a significant portion of these cases (69 locations).<sup>221</sup>

Energy development was deemed the likely cause of 60 seismic occurrences in the United States primarily in the southern states and coastal regions, but North Dakota was not mentioned in the report.<sup>222</sup> Even so, the majority of wastewater injections appear not to cause earthquakes.<sup>223</sup> If deep well injection occurs in a known fault location, however, the increase in pore pressure on the fault results in a reduction of normal fault pressure that allows the fault to slip more readily.<sup>224</sup> The fault may have had a balance of friction until the injection reduced that friction through an increase in pore pressure; if so, the injection did not necessarily cause the movement of the fault but accelerated the

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<sup>219</sup> Petersen et al., *2016 One-Year Seismic Hazard Forecast for the Central and Eastern United States from Induced and Natural Earthquakes*, 2.

<sup>220</sup> Ground Water Protection Council and Interstate Oil and Gas Compact Commission, *Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation* (Bismarck, ND: Ground Water Protection Council and Interstate Oil and Gas Compact Commission, 2015), 14.

<sup>221</sup> Davies et al., “Induced Seismicity and Hydraulic Fracturing for the Recovery of Hydrocarbons,” 14.

<sup>222</sup> Ground Water Protection Council and Interstate Oil and Gas Compact Commission, *Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation*, 14.

<sup>223</sup> Davies et al., “Induced Seismicity and Hydraulic Fracturing for the Recovery of Hydrocarbons,” 183.

<sup>224</sup> Ground Water Protection Council and Interstate Oil and Gas Compact Commission, *Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation*, 15.

movement.<sup>225</sup> In addition, the injection can occasionally activate previously unknown faults.<sup>226</sup>

As part of the USGS Earthquake Hazard Program, three earthquakes have been identified in North Dakota during the timeframe of deep well injection of wastewater. The first earthquake occurred on September 29, 2012, in North Dakota and measured 3.3 on the Richter scale.<sup>227</sup> The second on February 25, 2015, which occurred at 51km SSW of Plentywood, Montana, measured 3.8.<sup>228</sup> The third on May 6, 2015, at 28 km SW of Sidney, Montana, measured 2.6.<sup>229</sup> The data indicate that deep well injection in the Bakken has not significantly raised seismic activity because North Dakota has few faults (see Figure 13).

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<sup>225</sup> Ground Water Protection Council and Interstate Oil and Gas Compact Commission, *Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation*, 15.

<sup>226</sup> Davies et al., “Induced Seismicity and Hydraulic Fracturing for the Recovery of Hydrocarbons,” 173.

<sup>227</sup> “Search Earthquake Archives, Earthquake Hazards Program,” accessed September 9, 2016, <http://earthquake.usgs.gov/earthquakes/search/>.

<sup>228</sup> Ibid.

<sup>229</sup> Ibid.



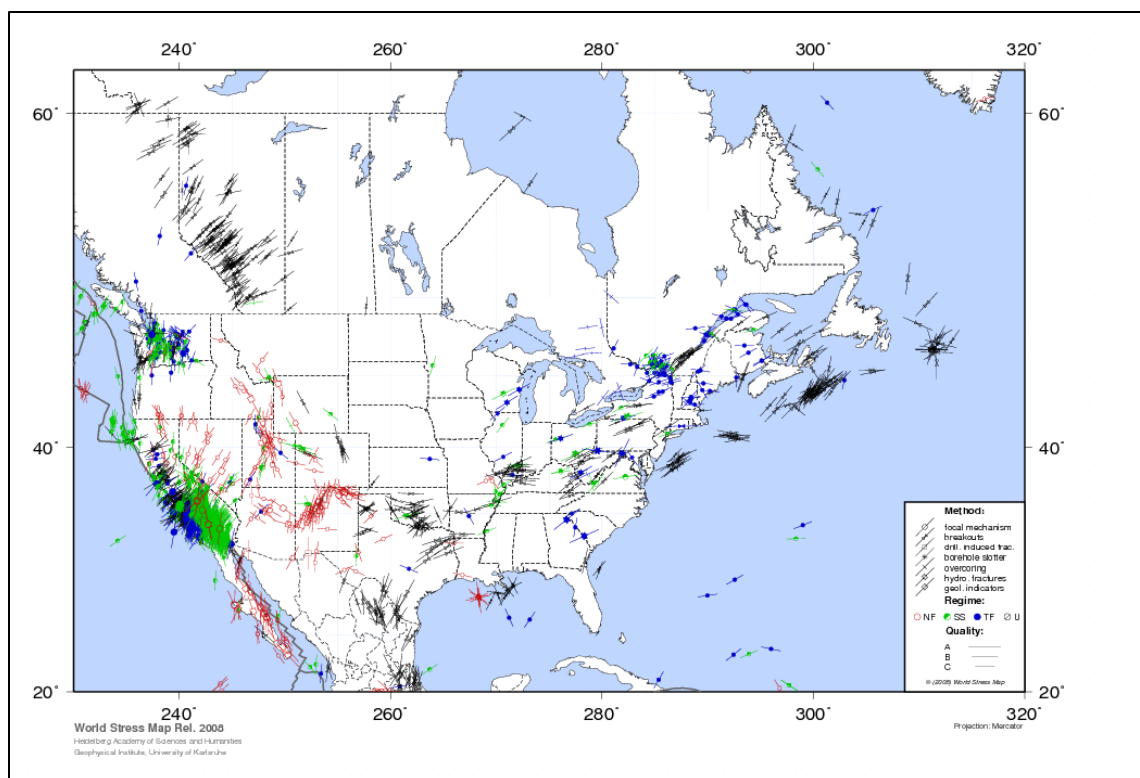


Figure 13. North American Fault Stress Map.<sup>230</sup>

## 6. Water Quality Concerns Resulting from Spills

The leading concern regarding the proper handling of wastewater is spill prevention, mitigation, and cleanup. Since spills are an inherent risk in the oil-production process, managing that risk is critical for policy makers.

In the Bakken, the risk of spills and the associated contamination of surface water is dramatically higher than the risk of groundwater contamination. In 2015, over 1,000 uncontained spills occurred in the four greatest oil-producing counties, Figure 14.<sup>231</sup> Since 2007, brine spills totaling 3,900 were reported in North Dakota.<sup>232</sup> The spill

<sup>230</sup> Source: “North American Stress Map,” 2008, <http://dc-app3-14.gfz-potsdam.de/pub/maps/namerica.gif>.

<sup>231</sup> “Environmental Incident Reports,” accessed September 9, 2016, <http://www.ndhealth.gov/ehs/spills/>.

<sup>232</sup> Nancy E. Lauer, Jennifer S. Harkness, and Avner Vengosh, “Brine Spills Associated with Unconventional Oil Development in North Dakota,” *Environmental Science & Technology*, April 27, 2016, A, doi: 10.1021/acs.est.5b06349.

volume typically ranged from 200 to 10,000 liters.<sup>233</sup> Pipeline leaks accounted for 18% of those releases, but they accounted for 47% of total spill volume. Improper pipeline connections and valves accounted for 24.8% of releases and 20.5% of total spill volume. Tank leaks and overflows accounted for 22.4% of releases and 14.5% of total spill volume.<sup>234</sup> Overall, failure of pipeline infrastructure played the largest role in those spills.

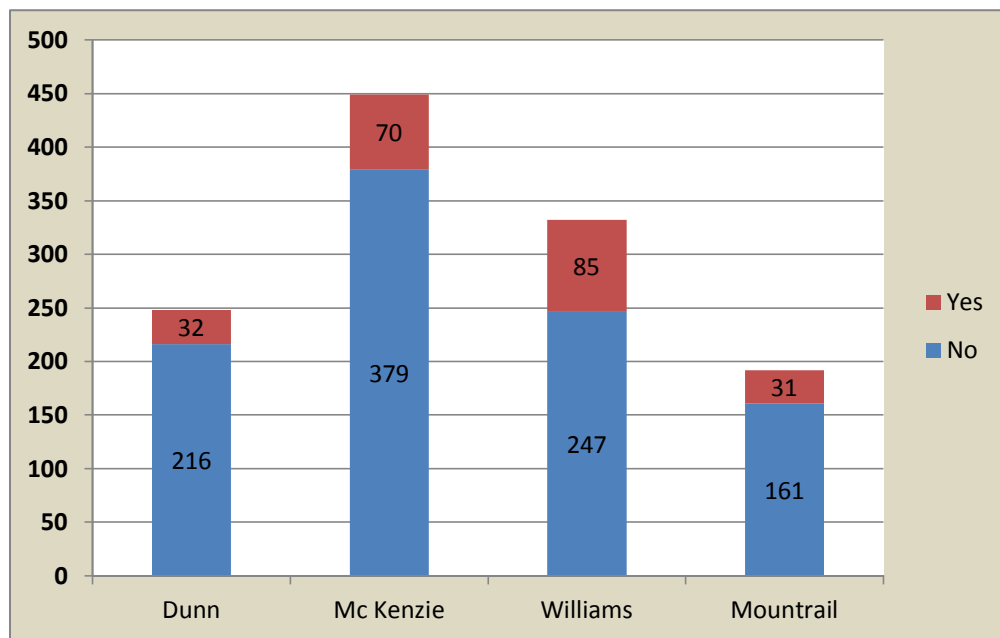


Figure 14. Containment Status of Reported Oil and Gas Spills in 2015.<sup>235</sup>

Brine spills have the potential to affect both groundwater and surface water quality.<sup>236</sup> In North Dakota, wastewater from oil and gas production is commonly transported through pipes and trucks and includes produced water, flowback, and

<sup>233</sup> Lauer, Harkness, and Vengosh, "Brine Spills Associated with Unconventional Oil Development in North Dakota," G.

<sup>234</sup> Ibid.

<sup>235</sup> Adapted from "Environmental Incident Reports." Contained releases are those that remain within the boundaries of the production or exploration facility. Not contained releases are those that overflow the boundaries of the facility or leak from a facility pipeline.

<sup>236</sup> Lauer, Harkness, and Vengosh, "Brine Spills Associated with Unconventional Oil Development in North Dakota," A.

saltwater from the formation (brine). Reported spills commonly occur during loading and unloading from storage tanks.<sup>237</sup> Other research has attributed the majority of brine contamination in the Williston Basin to the oil production practice of drilling pits, both unlined and lined.<sup>238</sup> “The release of OGW [Oil and Gas Wastewater] to the environment has been linked to salt, trace metal, and NORM [Naturally Occurring Radioactive Materials] contamination of local surface water, shallow groundwater, and stream sediments.”<sup>239</sup> Findings have indicated that brine spills are very persistent and have long-term effects on the drinking water system.<sup>240</sup>

Detecting a brine release can be challenging because highly mineralized water affects baseline results and can mask the detection of brine. Lauer, Harkness, and Vengosh found that the presence of high salinity in their samples alone was not indicative of a brine contamination because they also saw high salinity in the background samples.<sup>241</sup> They suggested “that accurate identification of OGW [Oil and Gas Water] in the environment in North Dakota requires several independent geochemical tracers”<sup>242</sup> and concluded that “Sr [strontium] isotopes are the most effective tracer of OGW in the environment in North Dakota, as they are not impacted by evaporation and cycles of salt precipitation and dissolution.”<sup>243</sup>

Lauer et al. found that the brine and surface waters at spill sites had trace metal levels one to two times higher than the background.<sup>244</sup> Levels exceed national environmental and drinking requirements at some spill sites.<sup>245</sup> They also found the brine

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<sup>237</sup> Lauer, Harkness, and Vengosh, “Brine Spills Associated with Unconventional Oil Development in North Dakota,” A.

<sup>238</sup> Preston and Chesley-Preston, “Risk Assessment of Brine Contamination to Aquatic Resources from Energy Development in Glacial Drift Deposits,” 535.

<sup>239</sup> Lauer, Harkness, and Vengosh, “Brine Spills Associated with Unconventional Oil Development in North Dakota,” A.

<sup>240</sup> *Ibid.*, G.

<sup>241</sup> *Ibid.*, E.

<sup>242</sup> *Ibid.*

<sup>243</sup> *Ibid.*

<sup>244</sup> *Ibid.*, G.

<sup>245</sup> *Ibid.*

in North Dakota very persistent and can remain in the environment for “at least months to years (up to 4 years for ND 128 and 129 samples) following the original spill.”<sup>246</sup> Practices have since changed to allow recognition of environmental impact; however, the persistence of brine, coupled with increased drilling and production, has resulted in an increased environmental risk.

## **7. Air Quality Concerns**

Air quality concerns associated with fracking and oil production include exposure to methane, volatile organic compounds (VOC), sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), fine particle matter (PM), and ozone (O<sub>3</sub>).<sup>247</sup> Exposure to SO<sub>2</sub> and NO<sub>x</sub> has been associated with short-term negative respiratory effects. Exposure to PM and O<sub>3</sub> has been associated with increased respiratory issues and hospital admissions, as well as possible early death.<sup>248</sup> Release of those air contaminants can occur throughout the oil-production process and pose a public health concern. That said, in terms of the power generation cycle, the production of natural gas from shale can result in a net reduction of greenhouse gases compared to the use of coal-fired power plants.<sup>249</sup>

The Bakken lacks the infrastructure to capture and move natural gas (methane) to market, so it is either flared or vented directly into the atmosphere. Venting natural gas can cause the resulting accumulation of methane and other gases to seek low-lying areas, a danger should they ignite.<sup>250</sup> Flaring is, therefore, the safer of the two options. The amount of natural gas being flared has decreased and continues to do so (see Figure 15). To encourage a reduction in flaring, community leaders in North Dakota have attempted to tax the royalties and quantity of flared natural gas; and oil industry leaders have tried

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<sup>246</sup> Lauer, Harkness, and Vengosh, “Brine Spills Associated with Unconventional Oil Development in North Dakota,” G.

<sup>247</sup> Ratner and Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, 9; Litovitz et al., “Estimation of Regional Air-Quality Damages from Marcellus Shale Natural Gas Extraction in Pennsylvania,” 3.

<sup>248</sup> Litovitz et al., “Estimation of Regional Air-Quality Damages from Marcellus Shale Natural Gas Extraction in Pennsylvania,” 3.

<sup>249</sup> *Ibid.*, 2.

<sup>250</sup> Neal Davis, “Natural Flaring in North Dakota Has Declines Sharply since 2014,” U.S. Energy Information Administration, June 13, 2016, 1, <http://www.eia.gov/todayinenergy/detail.cfm?id=26632#>.

to increase the infrastructure necessary to transport the natural gas to market.<sup>251</sup> A decrease in flaring should decrease the effects of burning natural gas and thus the production of carbon dioxide (CO<sub>2</sub>) and greenhouse gases.

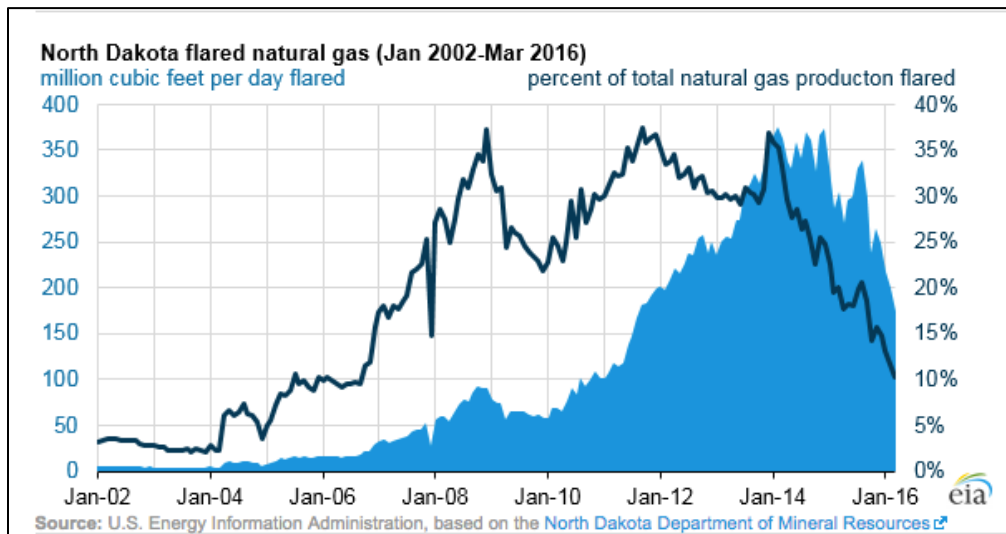


Figure 15. The Amount of Natural Gas Flared in North Dakota.<sup>252</sup>

Venting has been shown to impact air quality negatively in the Bakken region. In 2012, a long-term reversal of global ethane reductions was negated when Bakken ethane emissions reversed that trend.<sup>253</sup> The Bakken provides for 2% of U.S. shale gas production; however, it accounts for 1%–3% of total global ethane releases.<sup>254</sup> “The very heavy composition of raw gas in the Bakken shale (42% molar C<sub>2</sub>:C<sub>1</sub>) helps explain the relatively high emissions.”<sup>255</sup> These high emissions from the Bakken along with the Eagle

<sup>251</sup> Davis, “Natural Flaring in North Dakota Has Declines Sharply since 2014,” 1.

<sup>252</sup> Source: “Natural Gas (Jan 2002–Mar 2016),” accessed November 27, 2016, <https://www.flickr.com/photos/124982865@N08/27570988672/>.

<sup>253</sup> E. A. Kort et al., “Fugitive Emissions from the Bakken Shale Illustrate Role of Shale Production in Global Ethane Shift,” *Geophysical Research Letters*, January 1, 2016, 2, doi: 10.1002/2016GL068703.

<sup>254</sup> *Ibid.*, 5.

<sup>255</sup> *Ibid.*, 6.

Ford oil and gas play are to blame for its substantial contribution to ethane in the atmosphere.<sup>256</sup>

## B. CASE STUDY (SOCIOECONOMIC)

The energy boom in the Bakken has not only impacted the environment, but several researchers have also linked energy booms to the socioeconomic fabric of their communities.<sup>257</sup> The Bakken boom is no different; therefore, this research examined the effects in Williams County, North Dakota, in which the City of Williston had been proclaimed “Boomtown, USA” (see Figure 16). Socioeconomic impacts by collecting data on population growth, housing, tax structure and revenue distribution, infrastructure demands, and crime were evaluated.



Figure 16. Map of the Bakken.<sup>258</sup>

<sup>256</sup> Kort et al., “Fugitive Emissions from the Bakken Shale Illustrate Role of Shale Production in Global Ethane Shift,” *Geophysical Research Letters*, 6.

<sup>257</sup> Dalton, *Discussion Paper—Potential Socioeconomic Effects of Unconventional Oil and Gas Development in Nova Scotia Communities*; Jacquet, “Review of Risks to Communities from Shale Energy Development.”

<sup>258</sup> Source: Keith Schaefer, “The Montana Bakken Oil Play: ‘Great News for a Great Play,’” *Oil and Gas Investments Bulletin*, December 18, 2012, <https://oilandgas-investments.com/2012/investing/the-montana-bakken-oil-play/>.

Williston's proximity to the top four oil-producing counties of North Dakota has played a factor in its boomtown status. It is the largest community within the four counties of McKenzie, Williams, Mountrail, and Dunn. The development of the oil reserves required a workforce, heavy equipment, and support materials.<sup>259</sup> A dramatic influx of people and equipment impacts communities, especially rural communities like Williston in the Bakken.<sup>260</sup> The community faced a large increase in population, suffered a housing shortage, endured both economic benefits and hardships, experienced infrastructure demands, and witnessed increased crime. Benefits have also occurred, such as increased employment, availability of better paying jobs, increased income, growing government services, and increased tax revenue. This research examined the unintended consequences of the Bakken's oil development and how those unintended consequences have affected Williston, Williams County, and the State of North Dakota.

### **1. Williston before the Oil Boom**

Since 2000, the City of Williston has seen dramatic changes in population, income, and housing (see Table 2). Before the recent oil boom, Williston had been quite stable: The population growth was constant, housing and the cost of the rental market were normalized, and economic markers, such as the median household income and unemployment statistics, were steady. According to the U.S. Census Bureau, the City of Williston had a population of 12,512 in 2000 with a mean household income of \$36,672.<sup>261</sup> The U.S. Census Bureau has categorized the oil industry under mining, which falls into the industry grouping of agriculture, forestry, fishing and hunting, and mining. In 2000, this industry accounted for 8.5% of employment in Williston, its third leading industry behind professional services and retail.<sup>262</sup> The city was no stranger to the boom-and-bust concept, having experienced it in the 1950s, when oil was initially discovered, and again in the 1970s and 1980s. The last bust left numerous vacant

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<sup>259</sup> Jacquet, "Review of Risks to Communities from Shale Energy Development," 8321.

<sup>260</sup> Ibid.

<sup>261</sup> "American FactFinder: Community Facts," accessed September 3, 2016, <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.

<sup>262</sup> Ibid.

apartment buildings and houses along with bitter memories of the \$28 million debt that taxpayers had to service.<sup>263</sup>

Table 2. Comparative Analysis of the City of Williston’s Population, Employment, Income Levels, and Housing.<sup>264</sup>

<b>City of Williston</b>			
	<b>Pre-Boom (2000)</b>	<b>Peak (Year)</b>	<b>2016</b>
Population	12,512	26,977 (2016)	26,977
*% Of Population Employed in Oil Industry**	8.5	20.1 (2005–2009)	19.4
*Mean Household Income	\$36,672	\$104,161 (2010–2014)	\$104,161
*Housing Units	3,360	5,349 (2010–2014)	5,349
*Rental Units	1,895	2,944 (2010–2014)	2,944
*Homeowner Vacancy Rate	1.9%	0.0% (2010, 2011, & 2012)	1.1%
*Renter Vacancy Rate	17.0%	1.4%* (2010–2014)	5.7%

\* Data Retrieved from the U.S. Census Bureau, 2005–2009, 2006–2010, 2007–2011, 2008–2012, 2009–2013, 2010–2014 American Community Survey 5-Year Estimates

\*\*Includes the industries of agriculture, forestry, fishing and hunting, and mining (which includes oil and gas)

## 2. Population In-Migration

Population growth places stress on a community’s businesses, roads, public infrastructure, housing, emergency services, and social services.<sup>265</sup> Effective management of those stressors requires effective planning, public input, and proper governance.<sup>266</sup> Adding to the difficulty of planning is the market volatility of oil.

<sup>263</sup> Killelea, “Boomtown USA,” 26.

<sup>264</sup> Adapted from “American FactFinder: Community Facts.”

<sup>265</sup> Mitchell J. Small et al., “Risks and Risk Governance in Unconventional Shale Gas Development,” *Environmental Science & Technology* 48, no. 15 (August 5, 2014): 8292, doi: 10.1021/es502111u.

<sup>266</sup> Ibid.



The latest Williston oil boom occurred as people throughout the United States suffered from the 2008 recession. As growth occurred in the energy sector of North Dakota, a phenomenon resembling the “gold rush” developed as people sought the associated high-paying jobs. Oil field workers poured into Williston, increasing the population by 116.7% in seven years (see Table 2 and Figure 17);<sup>267</sup> however, this number may underestimate the growth because transient oil workers were excluded from census data.<sup>268</sup>

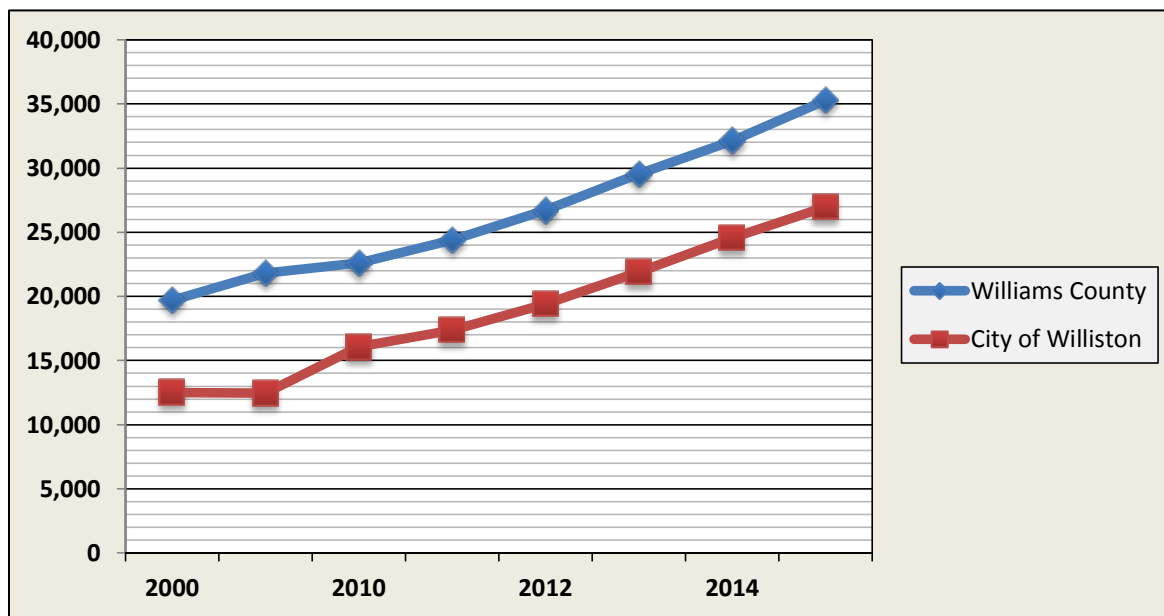


Figure 17. Population Trends in Williams County, North Dakota.<sup>269</sup>

Researchers from North Dakota State University (NDSU) Extension Service with community stakeholders, government officials, community leaders, healthcare professionals, and social service workers found that formerly quiet communities experienced “increased pressures on infrastructure, clashes of values, and [the displacement of] individuals and families. Those who lived in the communities before the

<sup>267</sup> “American FactFinder: Community Facts.”

<sup>268</sup> “Population Study Says Williston Could Have 44,000 By 2017,” December 13, 2012, <https://oilpatchdispatch.areavoices.com/2012/12/13/study-says-williston-could-have-44000-by-2017/>.

<sup>269</sup> Adapted from “American FactFinder: Community Facts.”

boom miss[ed] the familiarity of what ‘was a farm community but [had become] a gold rush state.’”<sup>270</sup> Rural communities expanded so quickly that citizens grew suspicious of others when they no longer knew their neighbors.<sup>271</sup> Concern developed among some residents who had planned to retire in the community but reconsidered leaving to escape the chaos brought by the oil boom.<sup>272</sup>

In 2007, the newly hired Director of Planning and Zoning for Williston said, “Other cities had 50 to 60 years of uninterrupted planning,” but Williston had to catch up.<sup>273</sup> In one study, the Williston population was expected to grow to nearly 40,000 by 2017.<sup>274</sup> In 2014, demographers believed that the City of Williston’s population would hit 50,000 within the next decade.<sup>275</sup> Faced with these growth scenarios, city leaders acted aggressively in planning for this rapid growth by annexing land near a city bypass and industrial area under construction to accommodate the heavy truck traffic associated with the oil and gas businesses.<sup>276</sup> In 2010, the City of Williston measured 4,571 acres, but through annexation, expanded threefold to 12,994 acres in 2014.<sup>277</sup>

**a.       *The Downturn in Population***

As the price of oil dropped, so did Williston’s population. The summer of 2015 saw an estimated population drop of 16% to 26,533, a number that city planners estimated by examining wastewater data. Although U.S. Census data are more accurate, retrieving them takes longer.<sup>278</sup> At the time of this writing, U.S. Census data did not yet

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<sup>270</sup> Bohnenkamp et al., *Concerns of the North Dakota Bakken Oil Counties*, 7.

<sup>271</sup> Ibid.

<sup>272</sup> Ibid.

<sup>273</sup> Killelea, “Boomtown USA,” 26.

<sup>274</sup> Nancy M. Hodur and Dean A. Bangsund, *Population Estimates for City of Williston* (Fargo, ND: Department of Agribusiness & Applied Economics, 2013), 26, <http://www.cityofwilliston.com/usrfiles/aud/docs/cityofwillistoncomprehensivereport062520132.pdf>.

<sup>275</sup> Killelea, “Boomtown USA,” 26; Ernest Scheyder, “In North Dakota’s Oil Patch, a Humbling Comedown,” *Reuters*, accessed May 18, 2016, <http://www.reuters.com/investigates/special-report/usa-northdakota-bust/>.

<sup>276</sup> Killelea, “Boomtown USA,” 27.

<sup>277</sup> Ibid.

<sup>278</sup> Scheyder, “In North Dakota’s Oil Patch, a Humbling Comedown.”

indicate the peaking of Williston's population; however, local wastewater data indicated a strong correlation between reduced rig counts and a population decline.

Nearly all boomtowns experience a rapid out-migration of population with subsequent high rates of unemployment, plummeting property values, and poverty.<sup>279</sup> Those experiences were evident in the energy boomtowns of the 1970s and 1980s, in which a large out-migration occurred between 1983 and 1985.<sup>280</sup> Studies of boomtowns have shown a significant decline in the quality of life and in community happiness during the down years, remaining depressed for about 20 years before returning satisfaction to preboom-year levels.<sup>281</sup>

### **3. Housing**

The rapid in-migration of workers placed stress on the Williston housing market, resulting in significant problems for its residents. The relatively low number of housing and rental units in the city along with the low pre-boom vacancy rate of 1.9% (Table 2) resulted in a very limited number of housing units for the additional people arriving to work in the oil fields.<sup>282</sup> The problem of supply and demand drove up rental and housing costs. Rent skyrocketed to the same level as some of the country's most prime real estate locations, such as Los Angeles, New York City, and Santa Barbara.<sup>283</sup> At one point, the going rate for a one-bedroom apartment in Williston was \$2,394 per month.<sup>284</sup> A lack of rent control prior to the boom resulted in some residents' rent going from \$300 to \$900 per month, posing a significant problem for residents.<sup>285</sup>

Housing costs became so elevated that long-time residents on fixed incomes were displaced.<sup>286</sup> Attracting employees to fill openings outside oil field-related jobs, such as

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<sup>279</sup> Jacquet, "Review of Risks to Communities from Shale Energy Development," 8322.

<sup>280</sup> Jacquet, "Review of Risks to Communities from Shale Energy Development."

<sup>281</sup> Jacquet, "Review of Risks to Communities from Shale Energy Development," 8321.

<sup>282</sup> "American FactFinder: Community Facts."

<sup>283</sup> Cwiak et al., *The New Normal*, 23.

<sup>284</sup> Ibid.

<sup>285</sup> Bohnenkamp et al., *Concerns of the North Dakota Bakken Oil Counties*, 8.

<sup>286</sup> Cwiak et al., *The New Normal*, 24.

retail, fuel services, medical, local schools, police, public works, and the food industry, became extremely difficult.<sup>287</sup> City of Williston leaders chose to build three apartment buildings to offer subsidized rent to city employees and to attract and retain its staff, offered a \$1,050 quarterly bonus for every city employee, allowing the city to increase its staffing from 102 to 198 employees.<sup>288</sup> To pay for the staffing increase, the housing subsidy, and the retention bonus, the City of Williston bonded for \$100 million in 2013.<sup>289</sup>

The increased demand for housing created a need to build more units, including houses, apartments, and temporary housing in the form of campers, hotels, and crew camps. In 2012, Williams County was home to an estimated 51,000 people, which included those staying in RV parks and crew camps.<sup>290</sup> Commonly referred to as man camps because they almost exclusively included male residents, crew camps provided an alternative housing option for many workers.<sup>291</sup> Target Logistics, the operator of a dormitory-style crew camp, was contracted for \$30 million to provide housing for the temporary oil workers.<sup>292</sup> Crew camps were constructed in a modular design so they could be moved in and set up as short-term housing,<sup>293</sup> and rent was typically subsidized by the oil industry.<sup>294</sup>

To accommodate the demand for housing, the number of residential building permits issued in Williams County, which includes Williston, rose along with the valuation of the subsequent construction projects (see Figure 18); but by 2015, the number of those permits dramatically decreased.

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<sup>287</sup> Ibid.

<sup>288</sup> Daniel Raimi and Richard G. Newell, *Shale Public Finance: Local Government Revenues and Costs Associated with Oil and Gas Development* (Durham, NC: Duke University Energy Initiative, 2014), 44–45, <http://dukespace.lib.duke.edu/dspace/handle/10161/9216>.

<sup>289</sup> Raimi and Richard G. Newell, *Shale Public Finance: Local Government Revenues and Costs Associated with Oil and Gas Development*, 44.

<sup>290</sup> “Population Study Says Williston Could Have 44,000 By 2017.”

<sup>291</sup> Killelea, “Boomtown USA.”

<sup>292</sup> Ibid., 27.

<sup>293</sup> Cwiak et al., *The New Normal*, 24.

<sup>294</sup> Ibid.

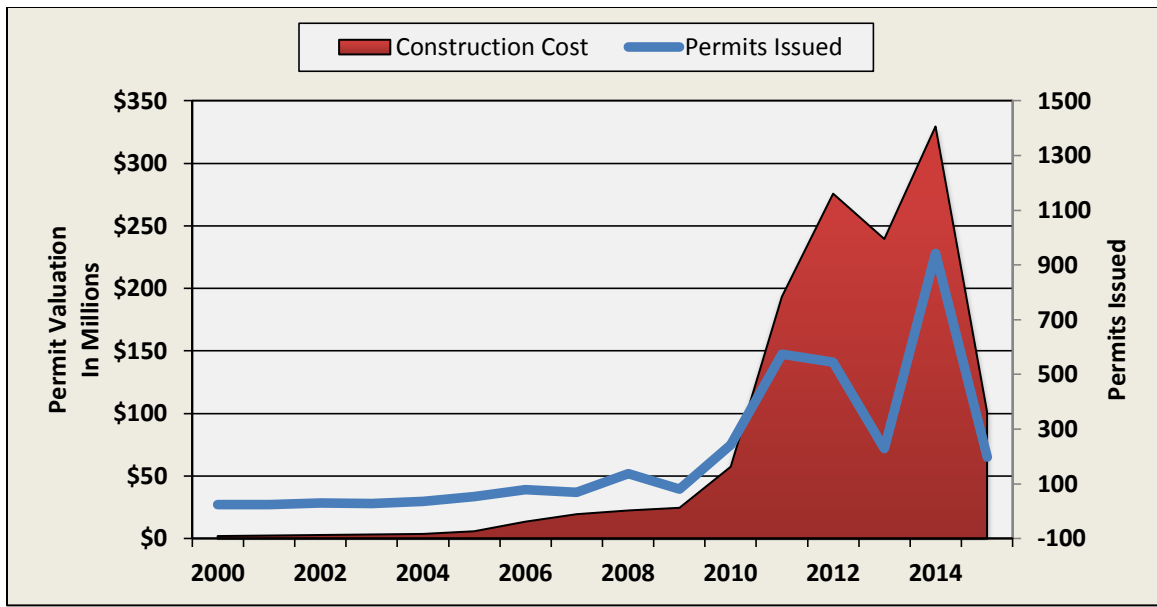


Figure 18. Construction Permits Trends in Williams County, North Dakota.<sup>295</sup>

*a. Housing Market Drop-Off*

In 2016, as Williston population numbers retracted, so did the demand for housing. From 2012 to 2016, the renter vacancy rate increased from 1.4% to 5.7% (see Table 2). A 330-unit Williston apartment complex stood unoccupied even after rates were reduced by 50%.<sup>296</sup> Since the fall of 2015, hotel prices dropped 23% to an average of \$99 per night, and most nights Williston’s 2,300 hotel rooms were only one-third occupied.<sup>297</sup> Vacancies included commercial space as well. A \$15 million building with retail, office, and residential space sat with over 50% residential space vacancies and 100% retail space vacancies.<sup>298</sup>

<sup>295</sup> Adapted from “American FactFinder: Community Facts.”

<sup>296</sup> Scheyder, “In North Dakota’s Oil Patch, a Humbling Comedown.”

<sup>297</sup> Ibid.

<sup>298</sup> Ibid.

#### 4. Economic Impact

Tax structure not only played a role in the profitability of oil and gas but also drove the economy because it was designed to help recoup the ancillary costs of providing services, such as infrastructure, government staffing, and public safety. Each state had its own formula for taxing oil and gas, and a wide variability existed in each oil- and gas-producing state as to the particular taxing formula used. Monitoring the tax structure was important because it affected the profit margin for oil and gas companies. Due to the influence it had on profitability, politicians exerted pressure to minimize taxing so that companies could maintain earnings.

In lieu of levying local property tax on the land on which oil was found, the State of North Dakota imposed two taxes on oil and gas production on oil companies that lease the mineral rights.<sup>299</sup> A portion of that tax was then distributed to the local and county governments through the state's budgeting process.<sup>300</sup> The first of the two taxes was a 5% tax on the gross value of the oil sold, called a production tax; producers were not required to pay taxes on any unsold oil, only the amount sold to a buyer.<sup>301</sup> The producer and the buyer were each required to submit a detailed monthly report to the North Dakota Tax Commissioner.<sup>302</sup> The second tax, imposed on the oil and gas that was extracted, was called an extraction tax. The tax rate was 6.5% of the gross value of the well;

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<sup>299</sup> North Dakota Tax Commissioner, *2014 State and Local Taxes: An Overview and Comparative Guide* (Bismarck, ND: North Dakota Tax Commissioner, n.d.), 67.

<sup>300</sup> Kelly L. Schmidt, "How is Oil and Gas Tax Revenue Distributed? Oil Extraction and Gross Distribution Fiscal Years 2016 and 2017," accessed September 6, 2016, <http://www.nd.gov/treasurer/how-is-oil-and-gas-tax-revenue-distributed/>.

<sup>301</sup> North Dakota Tax Commissioner, *2014 State and Local Taxes: An Overview and Comparative Guide*, 67.

<sup>302</sup> *Ibid.*, 68.

however, the taxing formula involved a lengthy list of sliding tax scales and exemptions<sup>303</sup> that allowed the flexibility to incentivize producers to explore more potential sites and drill new wells.<sup>304</sup>

Oil and gas tax collections in North Dakota affected the state's budget. Combined, the two collections were called a severance tax,<sup>305</sup> which amounted to \$200 million in 2007 and rapidly grew to roughly \$1.6 billion in 2012 (see Figure 19).<sup>306</sup> Despite some very successful quarters of production, slumping oil prices since 2015 have had a dramatic effect on tax revenue. The first quarter of 2016 saw the lowest collection since the first quarter of 2010, totaling \$283 million.<sup>307</sup> The downturn in tax collection quickly affected the North Dakota budget. A \$300 million surplus in 2015 turned into a \$1 billion shortfall in less than a year.<sup>308</sup> Contributing to the budget shortfall was an oil extraction tax reduction; the legislature reduced this tax from 6.5% to 5%, resulting in an estimated \$200 million revenue loss from the state budget.<sup>309</sup> The deficit caused the governor of North Dakota to slash the state budget by 4.05%, saving approximately \$245 million over a two-year budget cycle.<sup>310</sup>

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<sup>303</sup> Ibid.

<sup>304</sup> Ibid., 69.

<sup>305</sup> "Oil & Gas Severance Tax," accessed September 6, 2016, <http://www.nd.gov/tax/oilgas/>.

<sup>306</sup> Raimi and Newell, *Shale Public Finance*, 40.

<sup>307</sup> "Quarterly Summary of State & Local Taxes: Not Seasonally Adjusted T53 Severance Taxes," accessed September 6, 2016, <http://www.census.gov/econ/currentdata/dbsearch?program=QTAX&startYear=1992&endYear=2016&categories=QTAXCAT1&dataType=TOTAL&geoLevel=US&adjusted=0&notAdjusted=1&errorData=0>.

<sup>308</sup> Scott Cohn, "Oil-Rigged States Face a Full-Blown Economic Budget Crisis," *CNBC*, June 28, 2016, <http://www.cnbc.com/2016/06/27/us-states-face-an-economic-budget-crisis-due-to-falling-oil-prices.html>.

<sup>309</sup> Neil Carlson, "ND Special Session: After Cutting Oil Tax, Legislators Now Making Statewide Budget Cuts," accessed September 6, 2016, <http://www.valleynewslive.com/content/news/ND-Special-Session-After-cutting-oil-tax-Legislators-now-making-statewide-budget-cuts-388972481.html>.

<sup>310</sup> "North Dakota Governor Orders Cuts amid \$1B Budget Shortfall," February 4, 2016, <http://www.cnsnews.com/news/article/north-dakota-governor-orders-cuts-amid-1b-budget-shortfall>.

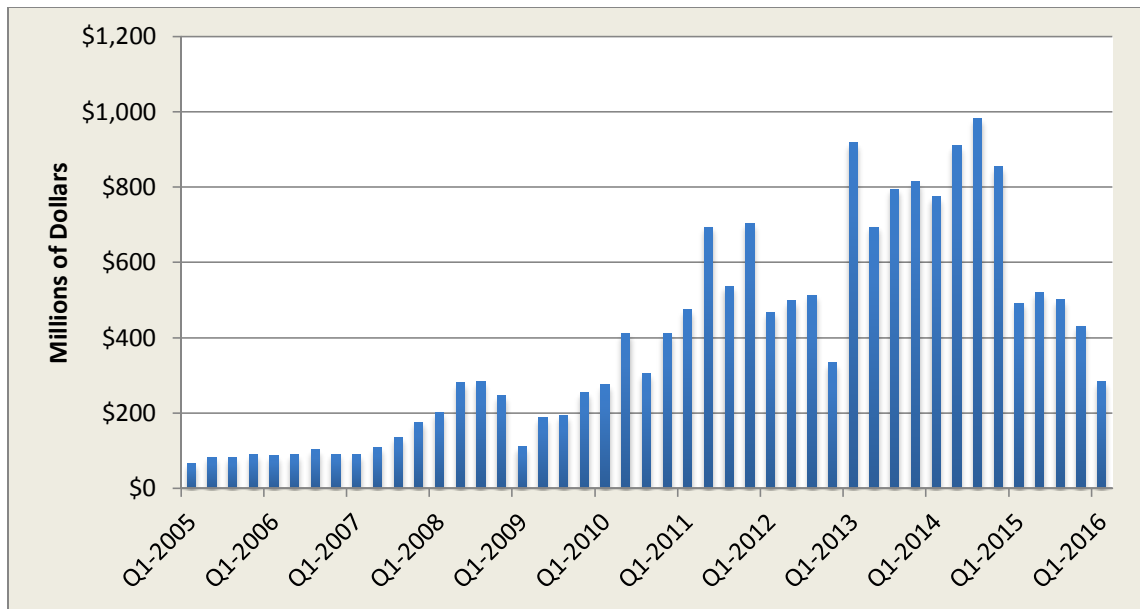


Figure 19. Trends of Severance Taxes Collected by the State of North Dakota.<sup>311</sup>

**a. *Distribution Payments to Local and County Governments***

A decline in state tax collection also affected the amount that cities, counties, school districts, and townships received as part of the tax distribution back to local and county government; therefore, declining state revenue hindered local governments in meeting their fiscal demands.

The North Dakota century code prescribed how both the oil and gas production tax and the oil extraction tax were distributed.<sup>312</sup> One fifth of the oil and gas production tax revenue was distributed to the cities, counties, and school districts in the oil producing region. Figure 20 identifies the tax distribution back to the top four North Dakota oil-producing counties, the City of Williston, and the Williston School District from both oil and gas taxes. Distribution to school districts began in 2013. The remaining revenue was distributed among all North Dakota cities, counties, school districts, and townships. The first \$5 million passes directly to local government agencies in oil-producing counties.

<sup>311</sup> Adapted from “American FactFinder: Community Facts.”

<sup>312</sup> North Dakota Legislative Branch, *Chapter 57-51 Oil and Gas Gross Production Tax* (Bismarck, ND: North Dakota Legislative Branch, n.d.), <http://www.legis.nd.gov/cencode/t57c51.pdf>.



For portions over \$5 million, 25% of the excess went to the oil-producing counties, and 75% went to the state.<sup>313</sup>

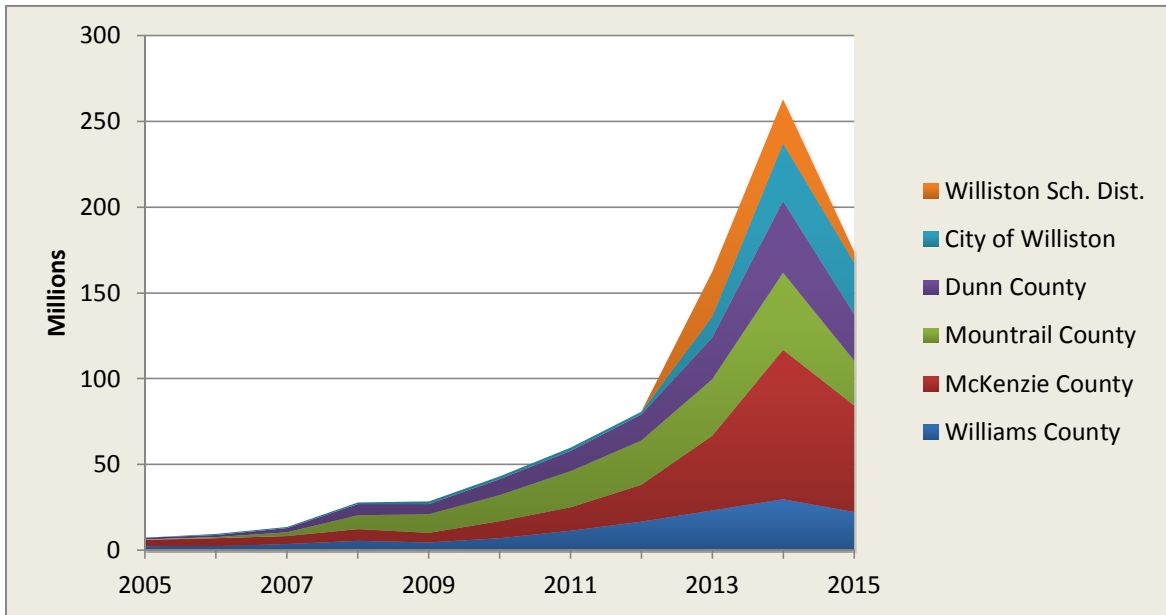


Figure 20. Distribution of Severance Taxes Back to the Top Four Oil Producing Counties.<sup>314</sup>

Figure 20 shows a sharp decline in distributions back to local government. Many communities relied on projections of population increases and the accompanying tax base increase, creating some dependence on, and expectation of, levels of state support that could no longer be met.

<sup>313</sup> North Dakota Tax Commissioner, *2014 State and Local Taxes: An Overview and Comparative Guide*, 76; Schmidt, “How is Oil and Gas Tax Revenue Distributed? Oil Extraction and Gross Distribution Fiscal Years 2016 and 2017.”

<sup>314</sup> Adapted from Kelly L. Schmidt, “Revenue Distribution—The Office of North Dakota State Treasurer,” *The Office of North Dakota State Treasurer*, accessed October 16, 2016, <http://www.nd.gov/treasurer/revenue-distribution/>.

Increased local expenditures have challenged local budgets. As decision makers became aware of projections showing long-term growth, pressures were placed on them to make long-term investments to entice citizens to remain after the boom was over. Williston's budget has grown since fracking began along with its growing trend of debt (see Figure 21). In 2008, Williston had \$15,092,958 in revenue and expenditures of \$15,814,016, resulting in a deficiency of \$721,058 or a negative 4.6% gap.<sup>315</sup> In 2014, the City of Williston had \$96,035,127 in revenue, a 536% increase from 2008.<sup>316</sup> The challenge was that their 2014 expenditures were \$173,217,070, a 995% increase over 2008.<sup>317</sup> The gap between income and expenses in 2014 was a negative \$77,181,943, a 44.6% loss.<sup>318</sup> The three largest factors on the expense ledger included \$78,121,952 for capital, principal payments, and interest service of \$47,825,786, which equaled \$125,947,738, or 73% of expenditures.<sup>319</sup> According to the Lucy Burns Institute, the average city spent roughly \$2,606 per citizen,<sup>320</sup> but in 2014, Williston spent \$173,217,070 for a population of 26,977 or \$6,421 per citizen!

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<sup>315</sup> Eide Bailly, *Financial Statements December 31, 2008* (Williston, ND: City of Williston, 2010), 16.

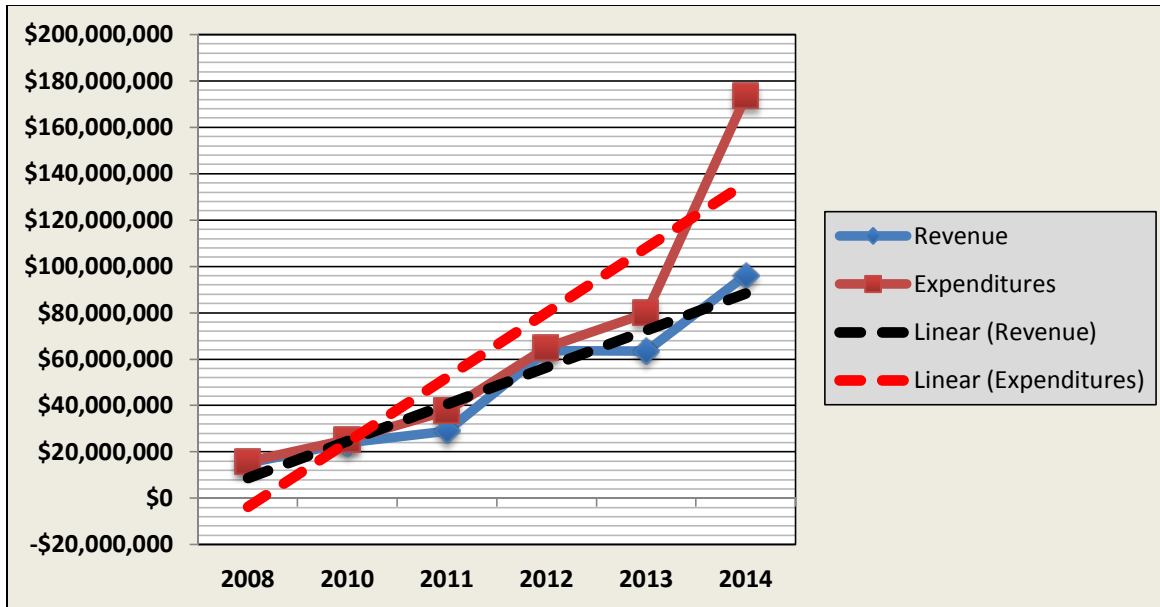
<sup>316</sup> Eide Bailly, *Financial Statements December 31, 2014* (Williston, ND: City of Williston, 2015), 10.

<sup>317</sup> Ibid.

<sup>318</sup> Ibid.

<sup>319</sup> Ibid.

<sup>320</sup> "Analysis of Spending in America's Largest Cities," April 2015, [https://ballotpedia.org/Analysis\\_of\\_spending\\_in\\_America%27s\\_largest\\_cities](https://ballotpedia.org/Analysis_of_spending_in_America%27s_largest_cities).



For 2008, 2010, 2011, 2012, 2013, 2014.

Figure 21. Trends in the City of Williston's Budget<sup>321</sup>

While important, severance tax from the State of North Dakota to the City of Williston was just one revenue source affected by the oil. The city's three largest revenue sources included property tax, local sales tax, and fees for services. Property tax collection grew from \$5.1 million in 2008 to \$60.9 million in 2014.<sup>322</sup> Sales tax collected in Williston grew from \$5.4 million to \$28.6 million over the same time period,<sup>323</sup> and fees for services within Williston expanded from \$7.3 million to \$28.2 million.<sup>324</sup> Over the years, those increases were significant (see Table 3).

<sup>321</sup> Adapted from "City of Williston, North Dakota—City Auditor," accessed October 16, 2016, <http://www.cityofwilliston.com/DepartmentHome.aspx?DeptID=AUD>.

<sup>322</sup> Bailly, *Financial Statements December 31, 2008*, 8; Bailly, *Financial Statements December 31, 2014*, 7.

<sup>323</sup> Ibid.

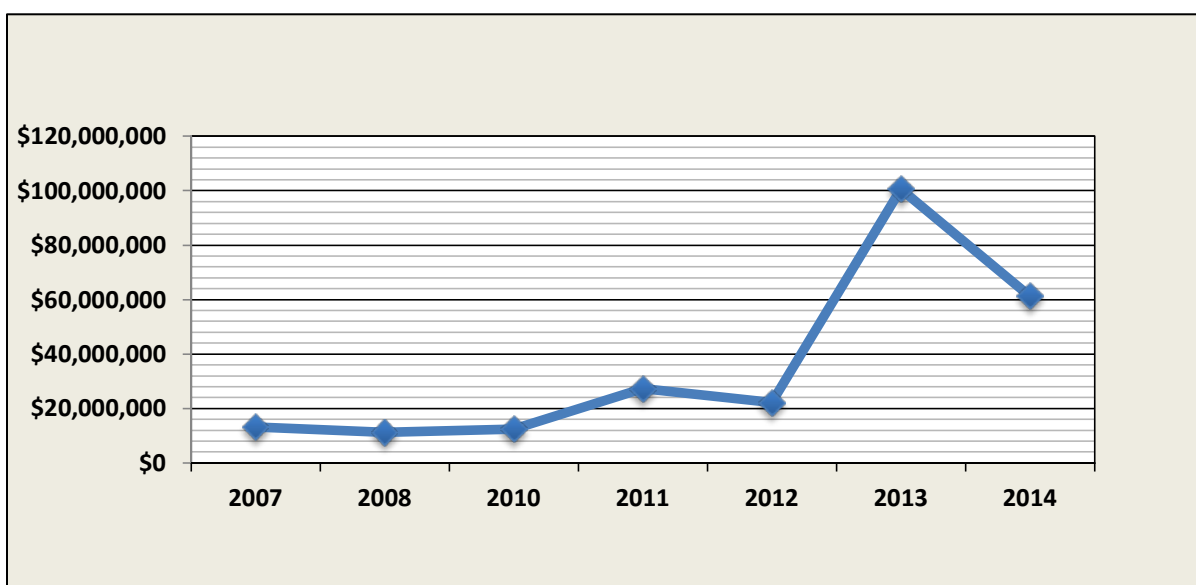
<sup>324</sup> Ibid.

Table 3. City of Williston Top Three Revenue Sources.<sup>325</sup>

	Sales Tax		Property Tax		Fees for Service	
	Total	% Change	Total	% Change	Total	% Change
2008	5,432,993		5,068,754		7,320,477	
2014	28,612,067	426.6	51,360,128	1,100.7	28,282,646	286.2

Years 2008 and 2014

The City of Williston had built up its governmental reserve fund, with the knowledge that it would eventually need to make decisions about future investments and expensive capital improvement projects. Surpluses in the governmental fund can help absorb some financial burden if revenue drops. Williston's reserve fund showed a significant decrease in 2014 yet was still better than in 2012 (see Figure 22).<sup>326</sup>



For 2008, 2010, 2011, 2012, 2013, 2014

Figure 22. Trends of the City of Williston Reserve Balance.<sup>327</sup>

<sup>325</sup> Adapted from "City of Williston, North Dakota—City Auditor."

<sup>326</sup> Bailly, *Financial Statements December 31, 2014*, 10.

<sup>327</sup> Adapted from "City of Williston, North Dakota—City Auditor."

Over the years, increases in the staffing and in the size of the fleet accompanied the increased demand for city services, having a significant impact on the city's annual operating budget.<sup>328</sup> The City of Williston saw its staff increase from 102 employees in 2008 to 198 in 2014.<sup>329</sup> Projections have indicated that by 2020, the city will need to hire an additional 260 employees, an estimated annual cost of \$20.4 million.<sup>330</sup> To accommodate the extra demand for services and staff, the city's fleet of vehicles was expected to increase from 116 in 2014 to 237 in 2020<sup>331</sup> at a cost of an estimated \$37.9 million.<sup>332</sup>

To meet the demand for community growth, from 2010 to 2014, Williston nearly tripled its landmass size through annexation, from 4,781 acres to 14,167 acres.<sup>333</sup> Since the launch of the oil boom, the city developed and platted 5,040 acres, with projections to continue to develop and plat an additional 3,900 acres.<sup>334</sup> The City of Williston has projected the need for an additional \$1.04 billion in infrastructure spending by 2020 to meet the demand for water, wastewater, storm water, transportation, and facilities.<sup>335</sup> The population growth and accompanying infrastructure needs have significantly influenced the city's budget.<sup>336</sup> The biennium from 2015 to 2017 can accommodate about half (\$494 million) of what is needed.<sup>337</sup>

The City of Williston has made a significant commitment to improving its city. To finance the investment, the city pledged much of its sales tax to the principal and

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<sup>328</sup> City of Williston, *Williston Energy Related Growth Impacts* (Williston, ND: City of Williston, 2015), 3, [www.willistonnd.com/usrimages/LegislativeBooklet12Jan2015V4.pdf](http://www.willistonnd.com/usrimages/LegislativeBooklet12Jan2015V4.pdf).

<sup>329</sup> Raimi and Newell, *Shale Public Finance*, 44; City of Williston, *Williston Energy Related Growth Impacts*, 3.

<sup>330</sup> City of Williston, *Williston Energy Related Growth Impacts*, 3.

<sup>331</sup> *Ibid.*

<sup>332</sup> *Ibid.*

<sup>333</sup> City of Williston, *Williston Energy Related Growth Impacts*, 1.

<sup>334</sup> *Ibid.*

<sup>335</sup> *Ibid.*, 2.

<sup>336</sup> *Ibid.*, 1.

<sup>337</sup> *Ibid.*, 2.

interest of the bond directed toward capital improvement projects.<sup>338</sup> Plans include a new \$240 million airport northwest of Williston. The land purchase agreement was completed in July 2016 with groundbreaking expected in October 2016.<sup>339</sup> As airline boardings increased, the new airport investment was intended to meet that demand (see Figure 23). Another capital improvement project included a \$70 million recreational center that opened in 2014, bonded and repaid through sales tax.<sup>340</sup> Future revenue was also pledged to repay bonds that added to an enterprise fund to pay for “construction and capital improvements to the City’s water treatment plant, sanitary sewer system, and landfill site.”<sup>341</sup> The repayment of that bond’s principal and interest came from a special fee on water, sewer, and landfill bills and a portion of state sales tax and the state’s oil and gas revenues.<sup>342</sup> The oil and gas revenue was to cover the bond principal and interest until the bond’s maturity in 2037.<sup>343</sup> Over 20 years of payments remain on the bond, and a fluctuation of variables that have been committed to pay for that bond has already been seen.

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<sup>338</sup> Bailly, *Financial Statements December 31, 2014*, 36.

<sup>339</sup> Associated Press, “Williston Completes Land Purchase Deals for \$240M Airport,” *Finance & Commerce*, accessed September 10, 2016, <http://finance-commerce.com/2016/07/williston-completes-land-purchase-deals-for-240m-airport/>.

<sup>340</sup> Paul Glader, “A \$70 Million Rec Center Brings Indoor Surfing, Golf to North Dakota,” *Bloomberg.com*, accessed September 10, 2016, <http://www.bloomberg.com/news/articles/2014-06-18/a-70-million-rec-center-brings-indoor-surfing-golf-to-north-dakota>.

<sup>341</sup> Bailly, *Financial Statements December 31, 2014*, 36.

<sup>342</sup> Bailly, *Financial Statements December 31, 2014*, 36.

<sup>343</sup> *Ibid.*

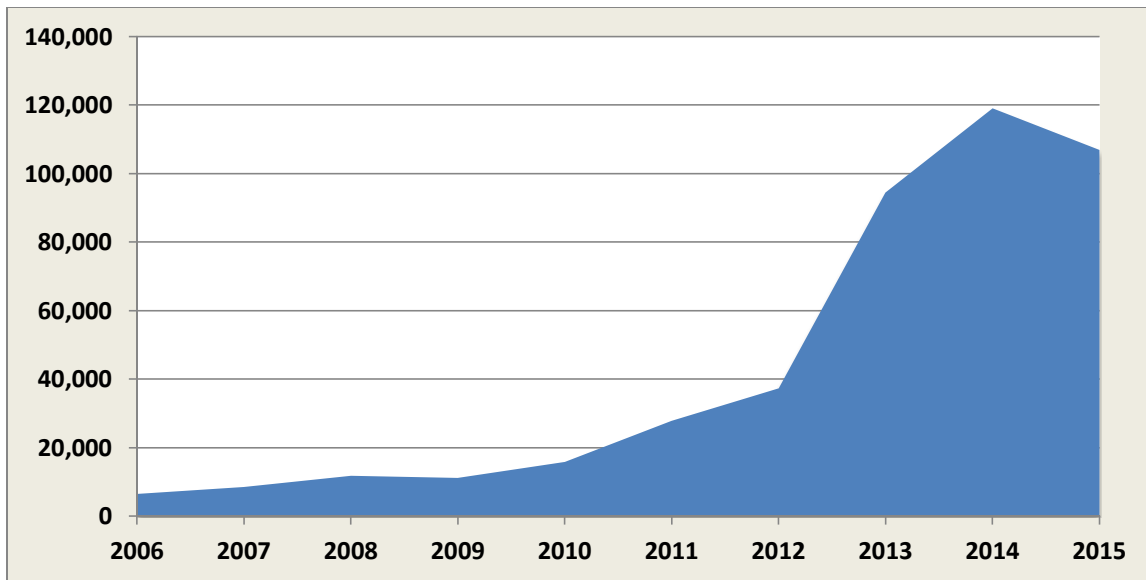


Figure 23. Aviation Boarding Trends from the Williston Airport.<sup>344</sup>

## 5. The Effects of Oil Collection Slowdown

A concern arose that North Dakota's trend of decreased oil and gas tax collections would severely impact the City of Williston's debt. The total city debt was expected to grow to \$673 million by the end of 2017, with the construction of the new airport and \$120 million in other capital improvement projects.<sup>345</sup> Growth projections based firmly upon Bakken crude were the primary basis for Williston's revenue commitments. Recognizing the problem of reliance on the state, the City of Williston developed a "comprehensive revenue and expense model to determine the funding gap the city . . . faces."<sup>346</sup> According to its analysis, the city would face a deficit of \$519 million by 2020 (see Figure 24).<sup>347</sup> Williston leaders estimated that the City would incur \$113 million in operating expenses and \$619 million in capital improvements by 2020, expenses that outpace its projected revenue of \$213 million for that year.<sup>348</sup> Oil and gas revenue were

<sup>344</sup> Adapted from "Aviation Statistics," accessed July 26, 2016, <https://aero.nd.gov/studies/aviation-statistics/>.

<sup>345</sup> City of Williston, *Williston Energy Related Growth Impacts*, 5.

<sup>346</sup> City of Williston, *Williston Energy Related Growth Impacts*, 4.

<sup>347</sup> *Ibid.*

<sup>348</sup> *Ibid.*

based upon oil cost projections of \$50/barrel for 2015–2017 and \$60 to \$70/barrel for the remaining years.<sup>349</sup>

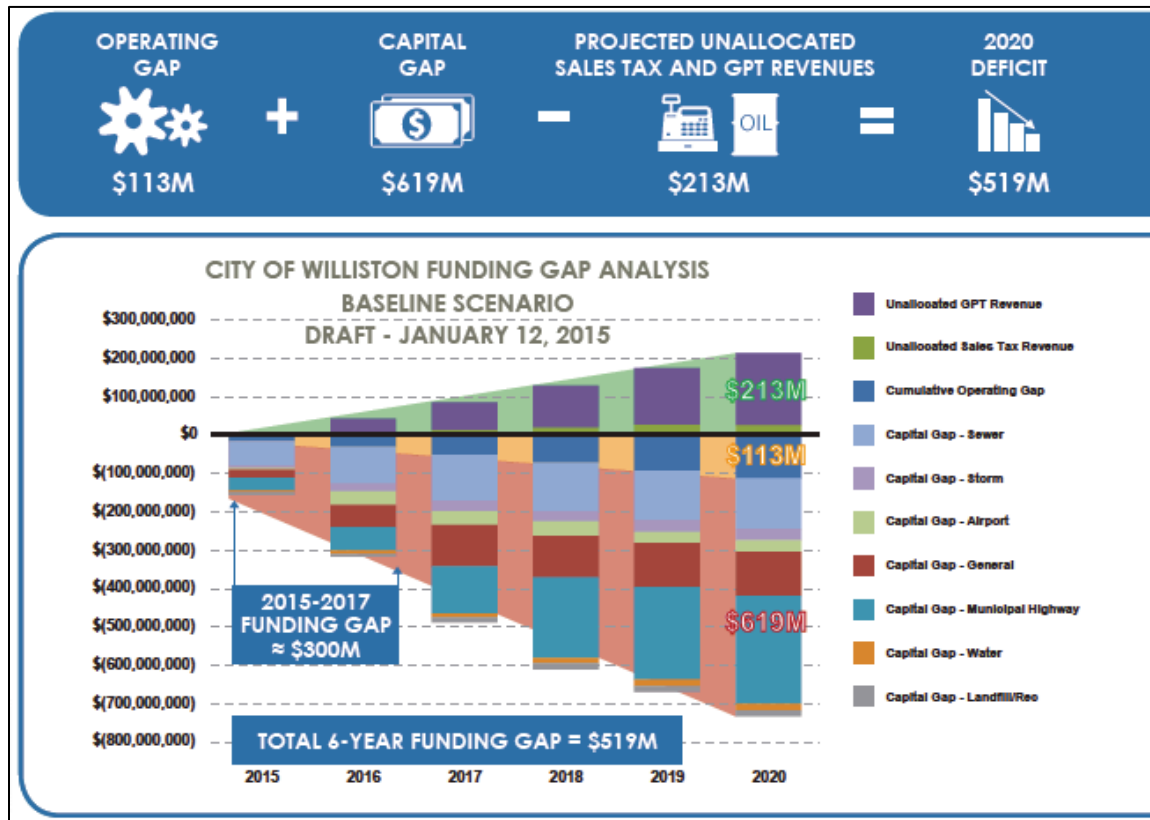


Figure 24. City of Williston’s Comprehensive Revenue and Expense Model.<sup>350</sup>

The decisions to bond infrastructure improvements and increase the size of the city drove up Williston’s deficit. For the biennium 2013–2015, the City of Williston committed \$323 million to critical infrastructure.<sup>351</sup> A deficit can compound when revenue decreases from both sales tax and oil and gas tax. Williston’s sales tax revenue was down 47% from March 2015 to March 2016.<sup>352</sup> Moody’s reduced Williston’s bond

<sup>349</sup> Ibid.

<sup>350</sup> Source: City of Williston, *Williston Energy Related Growth Impacts*.

<sup>351</sup> City of Williston, *Williston Energy Related Growth Impacts*, 5.

<sup>352</sup> Scheyder, “In North Dakota’s Oil Patch, a Humbling Comedown.”



rating to junk bond status because of its heavy reliance on sales tax to repay debt.<sup>353</sup> According to a Moody's analyst, "Putting all your eggs in one basket can be very risky, and I think we're seeing that bear out in Williston and North Dakota now."<sup>354</sup>

To curb the growing funding gap, leaders in the City of Williston suggested means to increase its revenue. Additional sewer and landfill costs were a particular financial drain on city revenue.<sup>355</sup> One suggestion was to increase the city's sewer fee by 21% and its refuse fund by 5% for each of the next six years, after which these additional fees would cover sewer and landfill costs.<sup>356</sup> Another suggestion was to increase the city's property taxes.<sup>357</sup> Although the state of North Dakota imposed caps on property tax levels, Williston's tax rate at the time of this writing was below the ceiling. The city has proposed to increase its property tax rate to the cap of 5% per year for the foreseeable future.<sup>358</sup> To help infuse money for the new airport and other capital improvement projects, the City of Williston took out an \$83 million loan from the Bank of North Dakota. The city also received a \$125 million loan from the Department of Health for a new wastewater treatment facility.<sup>359</sup> Leaders of the City of Williston also suggested a 1% sale tax to help pay for the public safety needs of the community. If approved, the special tax could reduce an estimated \$76.2 million of the deficit.<sup>360</sup>

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<sup>353</sup> Ibid.

<sup>354</sup> Ibid., 5.

<sup>355</sup> City of Williston, *Williston Energy Related Growth Impacts*, 5.

<sup>356</sup> Ibid.

<sup>357</sup> Ibid.

<sup>358</sup> Ibid.

<sup>359</sup> Ibid.

<sup>360</sup> City of Williston, *Williston Energy Related Growth Impacts*, 5.

## 6. Unemployment Trends

Unemployment rates were kept low in the Bakken because of the large demand for workers, especially true during the 2008 recession, when people from around the country flocked to the area looking for high-paying jobs. From 2005 to 2013, an estimated 50,000 new workers arrived to work in the oil fields.<sup>361</sup> The largest employment gain was in the service and support of the oil workers, such as “construction, drilling, transportation, repairs, well maintenance, and a host of other service-based operations in the oil patch.”<sup>362</sup> Even when some parts of the country struggled with high unemployment, such as in March 2011, openings for 14,000 jobs were available in the Bakken.<sup>363</sup> The allure of high-paying oil jobs negatively impacted the filling of nonoil jobs in the area. To fill nonoil job vacancies, employers had to offer incentives;<sup>364</sup> For example, McDonalds was forced to offer a signing bonus and nursing homes offered a \$1,000 signing bonus for housekeepers.<sup>365</sup> Alternatively, some local businesses closed because they could not afford to pay oil-field wages and were unable to find workers.<sup>366</sup> With demand driving up wages, the household mean income (see Figure 25) outpaced the rest of North Dakota’s income growth.

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<sup>361</sup> Dean A. Bangsund and Nancy M. Hodur, *Petroleum Industry’s Economic Contributions to North Dakota in 2013* (Fargo, ND: North Dakota State University, 2015), 49.

<sup>362</sup> Ibid.

<sup>363</sup> Putz, Finken, and Goreham, *Sustainability in Natural Resource-Dependent Regions That Experienced Boom-Bust-Recovery Cycles*, 21.

<sup>364</sup> Ibid.

<sup>365</sup> Ibid.

<sup>366</sup> Bohnenkamp et al., *Concerns of the North Dakota Bakken Oil Counties*, 9.

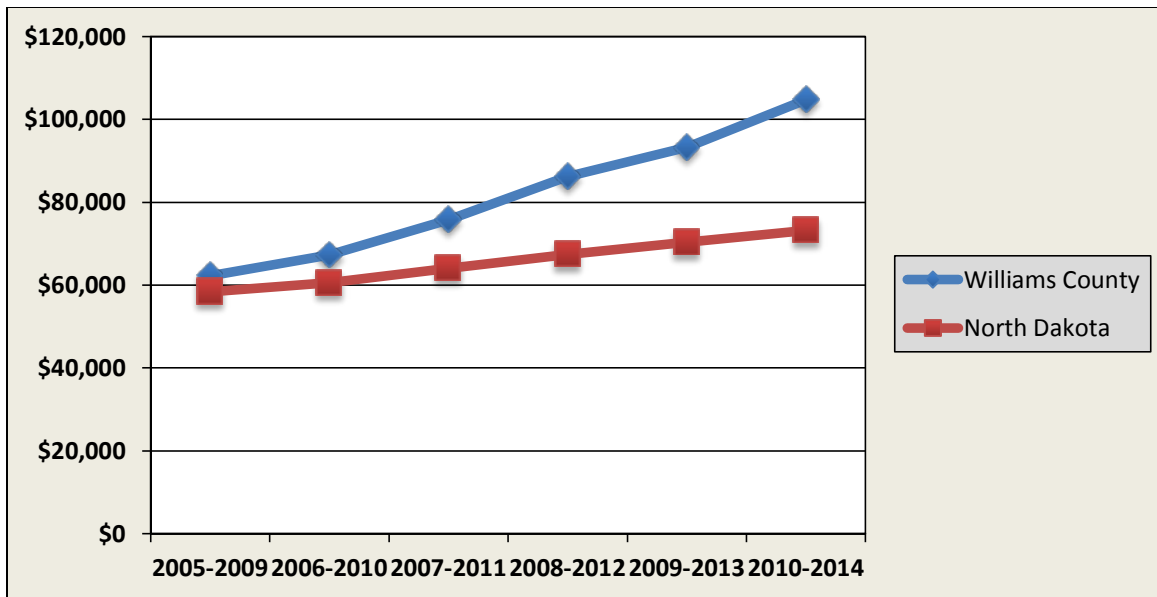


Figure 25. Trends in the Mean Household Income in Williams County, North Dakota.<sup>367</sup>

Based on the connection between demand and wage, the recent drop in oil prices was accompanied by a drop in wages. Since 2000, the unemployment rate in Williams County has fluctuated with oil production (see Figure 26). During the first quarter (January through March) of 2016, the average weekly wage declined by 14.2%.<sup>368</sup> “Until recently, oilfield roughnecks were making more than \$100,000 a year average. Few command those salaries today.”<sup>369</sup> With decreased demand for oil workers came decreased demand for nonoil workers. Walmart reduced its wages by 15% and the Salvation Army saw a reduction in donations.<sup>370</sup> Several businesses were forced to close, such as Home Depot in May 2016, and FedEx deliveries were reduced from three trips per day to one.<sup>371</sup> Once-crowded restaurants had empty tables: “Williston offered people

<sup>367</sup> Adapted from “American FactFinder: Community Facts.”

<sup>368</sup> Job Service North Dakota, “North Dakota Oil and Gas Economy,” September 7, 2016, 2.

<sup>369</sup> Scheyder, “In North Dakota’s Oil Patch, a Humbling Comedown.”

<sup>370</sup> Ibid.

<sup>371</sup> Ibid.

a chance to provide for their families and make a lot of money. . . . It's not the same anymore.”<sup>372</sup>

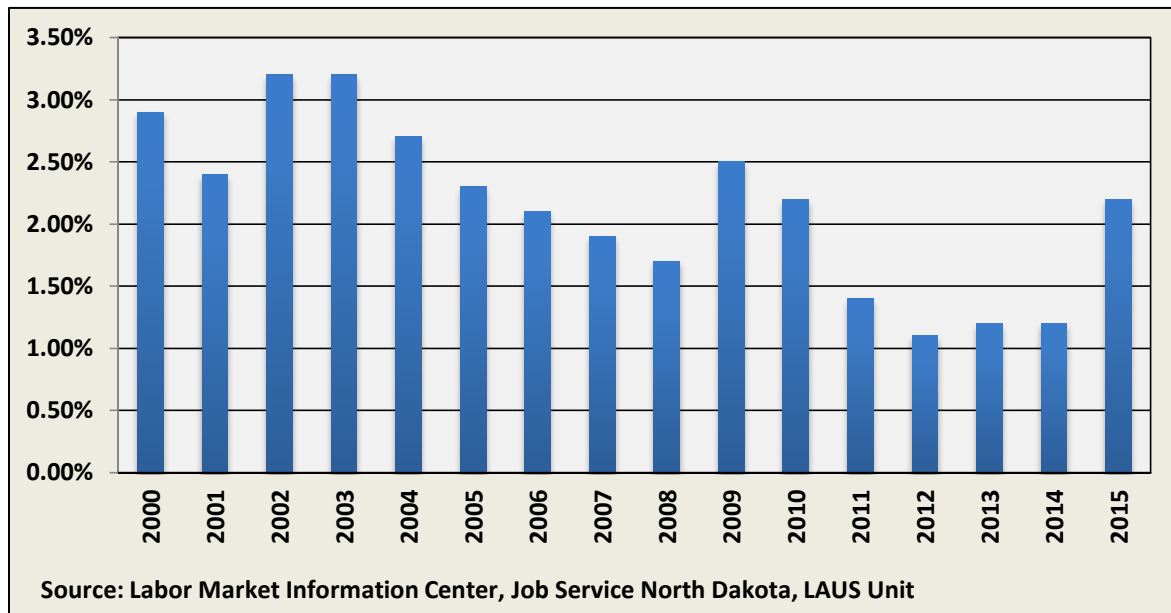


Figure 26. Unemployment Trend in Williams County, North Dakota.<sup>373</sup>

## 7. Crime

A positive association exists between antisocial behavior or crime and the migration of people during a boom and bust.<sup>374</sup> Unlike more natural community growth, when an energy boom has occurred, the demographics of a community change as a result of the variety of incoming people.<sup>375</sup> Much of the migrant workforce comprises young males with few ties to the community.<sup>376</sup> Research has indicated that life-long residents have expressed concern over a change in their community's quality of life and social

<sup>372</sup> Scheyder, "In North Dakota's Oil Patch, a Humbling Comedown."

<sup>373</sup> Adapted from "NDWIN—Home Page," accessed July 22, 2016, <https://www.ndworkforceintelligence.com/vosnet/lmi/default.aspx>.

<sup>374</sup> Ruddell et al., "Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties," 3.

<sup>375</sup> Ibid.

<sup>376</sup> Ibid.

concerns over traffic congestion and noncriminal acts.<sup>377</sup> Residents also express concern over alcohol-related issues, such as drunk driving.<sup>378</sup>

When a large in-migration from an energy boom occurs in rural areas, law enforcement becomes quickly overwhelmed and strained. Survey research of law enforcement agencies in the Bakken region showed findings similar to the already-existing research of energy boomtowns.<sup>379</sup> A key finding was the dramatic increase in call volume accompanying a population boom. Many of the increases involved “alcohol, traffic problems, and domestic violence.”<sup>380</sup> “Increases in calls for service, arrests, index crimes, fatal and non-fatal motor vehicle crashes, and sexual offenders, as well as significant turnover and recruitment issues have exacerbated the challenges by law enforcement agencies.”<sup>381</sup> As a result of the call volume, attitudes about policing changed. Many officers indicated the need to move from one call to another prioritizing them. One survey respondent stated, “I am less likely to take action with people in general because there is no time. If someone is speeding or if I think someone is drunk driving, I will let them go because I need to get on to the next call.”<sup>382</sup>

Many law enforcement agencies indicated the increase in calls included alcohol and young men.<sup>383</sup> They attributed those calls to the “bachelor culture” of the young males working in the oil field.<sup>384</sup> Assaults (usually bar brawls), disorderly conduct, and

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<sup>377</sup> Ruddell et al., “Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties,” 4.

<sup>378</sup> Ibid.

<sup>379</sup> Carol A. Archbold, Thorvald Dahle, and Rachel Jordan, “Policing ‘The Patch’: Police Response to Rapid Population Growth in Oil Boomtowns in Western North Dakota.,” *Police Quarterly* 17, no. 4 (December 2014): 22.

<sup>380</sup> Ibid.

<sup>381</sup> Ruddell et al., “Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties,” 4.

<sup>382</sup> Archbold, Dahle, and Jordan, “Policing ‘The Patch’: Police Response to Rapid Population Growth in Oil Boomtowns in Western North Dakota.,” 12.

<sup>383</sup> Ibid., 14.

<sup>384</sup> Ibid.

public intoxication were common criminal offenses occurring in or near local bars and strip clubs.”<sup>385</sup>

The Bakken’s social culture was also affected by the demographic change. Trust was relegated to the past. Long-time residents grew suspicious of others in the community and called police if they did not recognize those who lurked near their homes.<sup>386</sup> Those calls exacerbated the strain on law enforcement because looking unfamiliar is not illegal.<sup>387</sup> Adding to the strain was the inability of local law enforcement personnel to rely on knowledge of and relationships with community members; instead they had to focus solely on the facts of the call.<sup>388</sup> Many of their interactions involved someone who was under the influence of alcohol and carrying a gun legally or illegally;<sup>389</sup> consequently, officers grew more cautious in their responses.<sup>390</sup> Overall, the increase in calls hindered law enforcement officers’ interaction with the public in casual dialogue to build personal relationships.<sup>391</sup>

In 2012, the total crime rate reported in Williston reflected 10% of its population (see Figure 27). Based on FBI crime rate data from 2005 to 2012, larceny–theft, aggravated assault, violent crime, and property crime had the largest rate increases at 275%, 232%, 218%, and 202%, respectively (see Table 4).<sup>392</sup> A significant contributing detail in the changing crime in the area was the drastic spike in the murder–manslaughter rate. The crime statistics correlate with the perceptions of local law enforcement officers and Williston community members.

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<sup>385</sup> Archbold, Dahle, and Jordan, “Policing ‘The Patch’: Police Response to Rapid Population Growth in Oil Boomtowns in Western North Dakota,” 14.

<sup>386</sup> *Ibid.*, 15.

<sup>387</sup> *Ibid.*

<sup>388</sup> Ruddell et al., “Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties,” 21.

<sup>389</sup> Archbold, Dahle, and Jordan, “Policing ‘The Patch’: Police Response to Rapid Population Growth in Oil Boomtowns in Western North Dakota,” 17.

<sup>390</sup> *Ibid.*, 19.

<sup>391</sup> *Ibid.*, 23.

<sup>392</sup> “FBI—Crime Statistics,” accessed February 19, 2016, <https://www.fbi.gov/stats-services/crime-stats>.

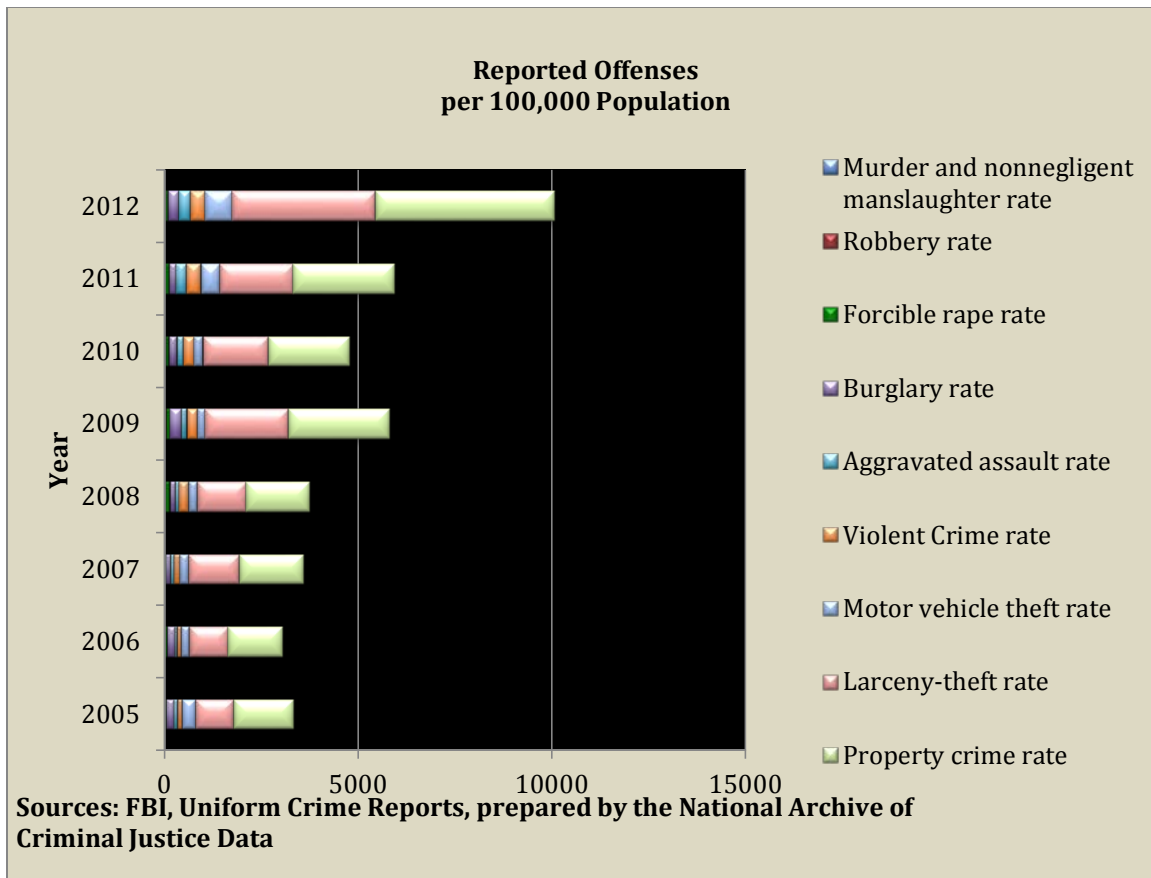


Figure 27. City of Williston, North Dakota, Crime Rates from 2005–2012.<sup>393</sup>

Table 4. Williston Crime Rate.<sup>394</sup>

Year	Violent Crime rate	Murder and Manslaughter rate	Rape rate	Robbery rate	Aggravated Assault rate	Property Crime rate	Burglary rate	Larceny/ Theft rate	Motor Vehicle Theft rate
2005	122.6	0.0	24.5	8.2	89.9	1,536.6	212.5	980.8	343.3
2012	390.9	6.1	73.3	12.2	299.3	4,641.8	268.7	3,682.9	690.2
% of CHG	<b>218.8</b>	<b>600.1</b>	<b>199.2</b>	<b>48.8</b>	<b>232.9</b>	<b>202.1</b>	<b>26.4</b>	<b>275.5</b>	<b>101.0</b>

<sup>393</sup> Adapted from “FBI—Crime Statistics.”

<sup>394</sup> Source: Ibid.

Traffic problems also accounted for increased call volume. In Williams County, traffic congestion caused by the large numbers of trucks needed for fracking resulted in a record number of accident fatalities.<sup>395</sup> Truck drivers hauling overweight loads, trucker fatigue from long work hours, and worsening road conditions following road degradation have created a dangerous combination.<sup>396</sup> As the well rig counts spiked in Williams County, so did traffic flow (see Figure 28).

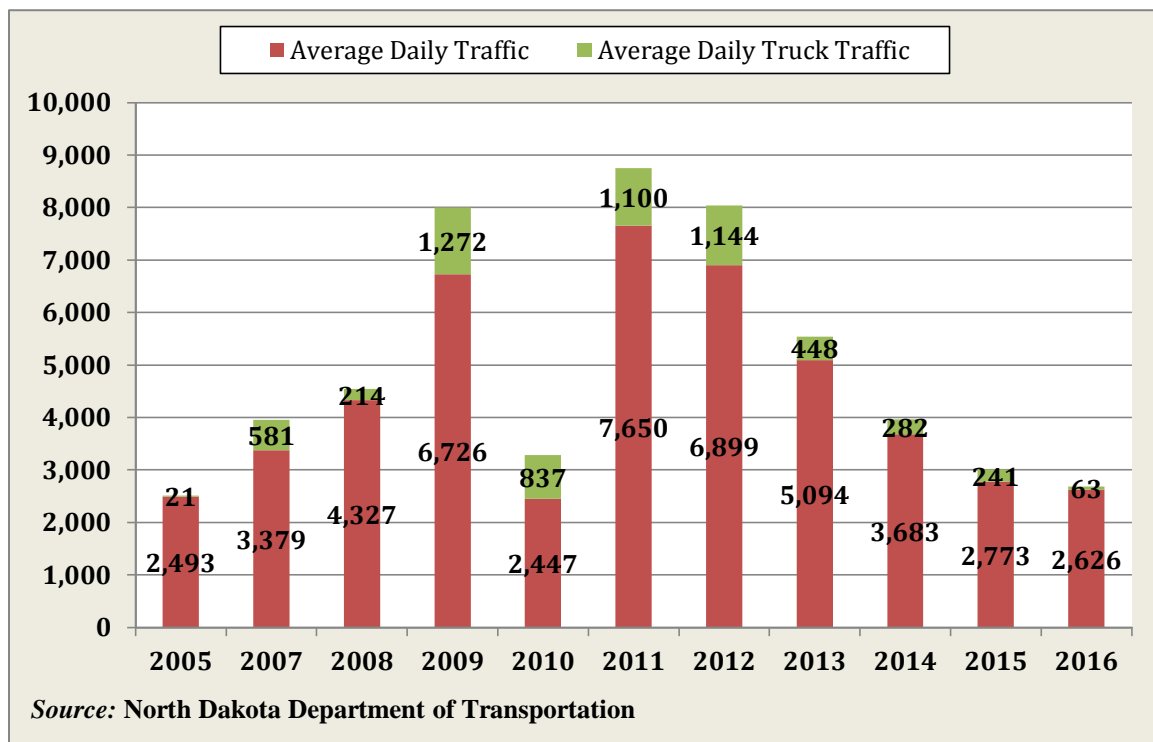


Figure 28. Daily Traffic Flow Averages in Williams County from 2005–2016.<sup>397</sup>

<sup>395</sup> Cwiak et al., *The New Normal*, 31.

<sup>396</sup> Ibid.

<sup>397</sup> Adapted from “NDDOT—County, Urban, and Traffic Information Maps,” accessed September 11, 2016, <https://www.dot.nd.gov/business/maps-portal.htm#trafficcountsstateandcity>.



## **V. DISCUSSION**

Natural resource extraction, including oil production and mineral consumption, have always entailed some degree of unintended consequences. The demand for accountability, however, poses great difficulty for policy makers who must include science-based confirmation of those consequences. Clearly, a full understanding of the extraction process allows for the prevention of, preparation for, and mitigation of adverse effects, but the controversial practice of fracking has been shrouded in misinformation and confusion, leaving local decision makers confused by the competing demands of the free-market and the need to protect their communities, doubly so when oil production profitability is very high and can influence decisions, as well as the narrative. In addition, those who live outside the affected location receive many of the benefits without personal impact; while everyone in the United States enjoys the lower price of gasoline, the local fracking communities suffer the negative impacts.

The purpose of this study was to increase awareness of the effects of unconventional shale oil exploration on local communities. Using the case study of the Bakken, publicly available data were examined to determine the impact of fracking in North Dakota. An attempt was made to identify causal links to understand how local communities can best prepare for, prevent, and mitigate unintended consequences to their environment and socioeconomic system. This thesis was undertaken to offer a clear understanding of consequences and to provide local policy makers with the information they need to protect their communities from the boom-and-bust cycles of economic activity, particularly with respect to the extraction of shale oil.

### **A. ENVIRONMENTAL IMPACTS**

According to available research, the most serious environmental impact to the Bakken–Three Forks area has been on water. Until 2000, the local hydrologic water cycle was balanced wherein consumption matched replenishment. Since 2000, however, that

balance has been upset.<sup>398</sup> Although industrial water usage was only 10% of the total between 2005 and 2015 (Figure 11), it represents a significant impact to the water cycle because that 10% represents a permanent removal of water from the previously balanced hydrologic cycle. That 10% corresponds to 32,599 acre-feet or 10.6 trillion gallons of water.<sup>399</sup> Of the water used for hydraulic fracturing, only 5% to 40% returns to the surface; and in North Dakota, deep well injection is used to dispose of the majority of the produced water.<sup>400</sup> Consequently, most water used for fracking in the Bakken is lost, either during the fracking process itself or through disposal as waste via deep-well injection; therefore, it stands to reason that a contributing factor in the declining water table is the water used for fracking. From 2005 to 2015, the amount of water used annually for industrial reasons in North Dakota increased by 78%, rising from 23,005 acre-feet in 2005 to 40,932 acre-feet in 2015 (Table 1). In 2014, the top four oil-producing counties consumed a combined total of 20,353 acre-feet (6,632,045,403 gallons) of water (Figure 12).<sup>401</sup> A contributing factor to the long-term decline of the groundwater supplies will be exacerbated by the increased demand for domestic water as population increases to service the fracking industry.

Although concerns over water contamination were raised, no definitive findings emerged about groundwater contamination in well samples. That said, the lack of definitive findings does not mean the risk is unfounded. A false negative could be attributed to a lack of connectivity between groundwater wells and the deeper disposal wells. The thick layers of rock formation that separate the two sources provide a buffer and protect the shallow groundwater sources.<sup>402</sup> A more likely cause of any water contamination comes from surface spills, which have the potential to impact surface and—eventually—groundwater sources. Despite the lack of definitive findings, brine

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<sup>398</sup> Long et al., *Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada*, 26.

<sup>399</sup> “Water Use Report.”

<sup>400</sup> Gallegos et al., “Hydraulic Fracturing Water Use Variability in the United States and Potential Environmental Implications,” 5844.

<sup>401</sup> “Water Use Report.”

<sup>402</sup> McMahon et al., “Quality and Age of Shallow Groundwater in the Bakken Formation Production Area, Williston Basin, Montana and North Dakota,” 87.

from the Bakken was shown to be very persistent, difficult to detect, and a risk to surface water sources.<sup>403</sup> According to the USGS, 71% of groundwater replenishment is from surface water sources; thus, keeping surface spills from contaminating surface water sources is critical in reducing the risk of groundwater contamination.<sup>404</sup>

The key finding in spill data is that many spills are preventable. The leading cause of spills was improper pipeline connections. Those connections could be secured through better control mechanisms or through better regulation of work practices that lead to improper connections. Pipelines could be engineered to have quicker or more frequent shutoffs to reduce spilled volume if something goes awry. Protective barriers and increasing protection for the exposed portion of the pipes would mitigate the risk of damaging pipes. Pipelines could also be better maintained, mediating problems more quickly. With 47% of spill volume coming from pipeline leaks, modifications could significantly reduce that risk.<sup>405</sup> Should the reality of spills remain, ensuring regulations and enforcement for proper cleanup of spills would reduce the cumulative impact of releases. In North Dakota, regulators knew about one of the largest land oil leaks in U.S. history and struggled with their transparency with the public that resulted in a loss of public trust in the state's ability to regulate the oil industry.<sup>406</sup>

The handling of produced water and injection wells in the Bakken is alarming because of the composition of the groundwater in the area. Those groundwater sources are naturally predisposed to high levels of TDS, possibly delaying or masking the discovery of a leaky injection well.<sup>407</sup> Despite the lack of a current definitive connection

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<sup>403</sup> Lauer, Harkness, and Vengosh, "Brine Spills Associated with Unconventional Oil Development in North Dakota," G-E.

<sup>404</sup> Long et al., *Conceptual Model of the Uppermost Principal Aquifer Systems in the Williston and Powder River Structural Basins, United States and Canada*, 13.

<sup>405</sup> Lauer, Harkness, and Vengosh, "Brine Spills Associated with Unconventional Oil Development in North Dakota," G.

<sup>406</sup> Associated Press, "North Dakota Oil Spill Cleanup Slowed by Lack of Natural Gas," *The Billings Gazette*, accessed October 4, 2016, [http://billingsgazette.com/news/state-and-regional/montana/north-dakota-oil-spill-cleanup-slowed-by-lack-of-natural/article\\_3c55068a-f9c5-52ae-ac09-f7b9a6a1a404.html](http://billingsgazette.com/news/state-and-regional/montana/north-dakota-oil-spill-cleanup-slowed-by-lack-of-natural/article_3c55068a-f9c5-52ae-ac09-f7b9a6a1a404.html).

<sup>407</sup> Torres, Yadav, and Khan, "A Review on Risk Assessment Techniques for Hydraulic Fracturing Water and Produced Water Management Implemented in Onshore Unconventional Oil and Gas Production," 482.

between Bakken disposal wells and water contamination, concern remains. Between 2010 and 2014, the speed and intensity with which the wells were drilled (Figure 6) easily overwhelmed the regulatory enforcement capability of the State of North Dakota.<sup>408</sup> Safe practices are difficult to ensure without appropriate regulation enforcement. One such safe practice is long-term monitoring to ensure the casing and wells do not leak as they age. As budgets become strained and companies take shortcuts to save money, long-term monitoring can become a real concern. Another possible concern is a reduction in funding for state regulators as a result of the loss of oil tax income. In addition, when violators of safe practices are fined and forced to perform remediation, sometimes those fines are reduced in an attempt to spur new investment for oil production.<sup>409</sup> North Dakota regulators have a history of levying fines and later reducing them to 10% of the original fine.<sup>410</sup>

Although a concern, the seismic activity associated with disposal injection wells is not an issue in the Bakken as it is in other regions of the United States. According to the USGS, the majority of wastewater injection wells do not cause earthquakes; however, they may contribute to the movement of the stressed tectonic plates.<sup>411</sup> Consequently, as long as wastewater is not injected into known stress faults, new fault motion should not be created. The Bakken seismic activity appears significantly different from other regions in which fracking is occurring, lacking identified stressed faults (Figure 13). From 1915 to 2012, the USGS identified only 13 earthquakes in the Bakken region attributable to the stability of the soil formation in North Dakota.<sup>412</sup> Since 2000, only three earthquakes have occurred in the Bakken region, the largest registering a 3.8 on the Richter scale in 2014.<sup>413</sup>

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<sup>408</sup> Deborah Sontag and Robert Gebeloff, "The Downside of the Boom," *New York Times*, November 22, 2014, <http://www.nytimes.com/interactive/2014/11/23/us/north-dakota-oil-boom-downside.html>.

<sup>409</sup> Ibid.

<sup>410</sup> Ibid.

<sup>411</sup> Davies et al., "Induced Seismicity and Hydraulic Fracturing for the Recovery of Hydrocarbons," 183.

<sup>412</sup> Donovan, "Earthquakes Not North Dakota's Problem."

<sup>413</sup> "Search Earthquake Archives, Earthquake Hazards Program."

The impact on air quality is a concern because of the volume of gas that is flared or vented. That volume exists because of a lack of infrastructure that can move the natural gas to market. Data show that long-term global ethane levels were on a decline until shale oil production began.<sup>414</sup> North Dakota plays a major role in those ethane levels. Although only 2% of the gas produced from shale is from the Bakken, it accounts for 1% to 3% of the ethane in the global atmosphere.<sup>415</sup> The processes of venting and flaring each have negative impacts. Flaring is the primary method of managing natural gas in the Bakken and has been attributed to an increase in greenhouse emissions.<sup>416</sup> Flaring and venting have doubtless had a negative impact on air quality. Infrastructure is needed so natural gas can be properly collected and sold as a consumable commodity, thereby reducing the risk to the environment and workers.

Through awareness, communities can prepare for, prevent, or mitigate the environmental impacts of shale oil production. In this research, causal links have been identified between shale oil extraction and concerns with water consumption, water quality, and air quality, consistent with research based on other shale oil production locations in the United States. The lack of faults in the region, however, makes the risk of fracking-induced seismic activity very low in the Bakken.

## **B. SOCIOECONOMIC IMPACTS**

Many socioeconomic impacts on the Bakken correlate with those associated with a typical boom-and-bust cycle associated with the exploitation of natural resources. The researcher believes that those impacts are still playing out in Williston, making it an excellent case study for other communities. What has impacted the area most is neither a matter of profitability of the shale oil nor the significant quantity of such oil in the Bakken; but instead, it is the people flocking to Williston looking for high-paying jobs. A contributing factor in the in-migration is the national economic recession of 2008,

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<sup>414</sup> Kort et al., “Fugitive Emissions from the Bakken Shale Illustrate Role of Shale Production in Global Ethane Shift,” 2.

<sup>415</sup> Ibid., 5.

<sup>416</sup> Ratner and Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, 9.

prompting more people from throughout the United States to look for work. The immigration of workers exacerbated the already limited housing market in the Bakken. The imbalance between supply and demand for housing led people to pay a premium for lodging and drove unprecedented increases in rent and housing prices. That inflation made Williston a prime location for real estate investment, particularly during the early years, because of limited options and the desperation it caused. High-paying jobs provided those in the oil sector much more disposable income to afford high housing rates, compared to the native population, many of whom were on fixed incomes or working outside the oil industry.

Demographics in the community of Williston changed dramatically. Young male workers from the oil field brought with them adolescent behavior that included a penchant for drinking and antisocial behavior, which frayed the long-term social fabric of the community. The influx of people looking for quick money instead of long-term community engagement caused tension between the preexisting residents and the newcomers. The demographic changes and their consequences are not new and correlate with the many boom-and-bust cycles that typically follow the gold rushes, oil discoveries, and mining operations associated with rapid industrialization.<sup>417</sup>

The dramatic population growth of Williston (Figure 17) has caused growing pains for government and elected officials. Demographic researchers have predicted a doubling of the population by 2024, placing pressure on local officials to invest in long-term infrastructure needs, such as new water treatment facilities, new roads, a new airport, and a new aquatic facility, to name a few.<sup>418</sup> The infrastructure investment has consumed much of the current and future local tax collections and the severance tax disbursed from the state. The City of Williston swiftly captured the boom of tax revenue from local sales tax, property tax (Table 3), and oil tax disbursement (Figure 20) from the State of North Dakota, increasing the city's financial assets. The rapid rise in the city's

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<sup>417</sup> Jacquet, "Review of Risks to Communities from Shale Energy Development," 8322; Perry, "Environmental Reviews and Case Studies: Addressing the Societal Costs of Unconventional Oil and Gas Exploration and Production: A Framework for Evaluating Short-Term, Future, and Cumulative Risks and Uncertainties of Hydrofracking," 357–360.

<sup>418</sup> Killelea, "Boomtown USA," 26.

income has created dependence upon a presumption of long-term income. That presumed income was then used to calculate future investments. The danger of being lured into the false security of a long-term booming economy is the inevitable pain that accompanies the bust, currently felt as the local and state economy of North Dakota retracts to a more typical level. The unemployment rate is just one example of the economy returning to a preboom level (Figure 26). Although current data do not indicate a decline in income level, the reported vacancy rates of homes, apartments, and hotels are on the rise (Table 2), associated with a decline in drilling and the impact that oil field workers have on the local economy.<sup>419</sup> Another signal of the retraction of Williston's economy is the reduction of building permits and the valuation of those permits (Figure 18). Building reduction indicates a steep drop-off to near preboom levels, which is concerning because it could also indicate overexpansion that exposes investors and developers to a higher level of bankruptcy and property foreclosures. Any loss of property is accompanied by a loss of revenue from property taxes. Bankruptcy can lead to a decline in a community's society and economy, similar to the impacts of the great recession of 2008.<sup>420</sup>

Unfortunately, the crime rate and workload for law enforcement have increased, not decreased, a common occurrence with a boom and bust.<sup>421</sup> The in-migration of mostly young males to work the oil fields has brought additional crime and work for local law enforcement. Ironically, as the population has stagnated, the crime rate has continued to grow (Figure 27). From 2005 to 2012, the total crime rate has more than doubled with the largest increases in larceny-theft, aggravated assault, violent crime, and property crime attributable to the change in demographics from the in-migration of workers.<sup>422</sup> A reduction in income and employment opportunities and an increase in socioeconomic stressors are naturally related to an increase in crime. The leading transgressions of

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<sup>419</sup> "American FactFinder: Community Facts"; Scheyder, "In North Dakota's Oil Patch, a Humbling Comedown."

<sup>420</sup> Ray Brescia and John Travis Marshall, *How Cities Will Save the World: Urban Innovation in the Face of Population Flows, Climate Change and Economic Inequality* (New York: Routledge, 2016), 12.

<sup>421</sup> Ruddell et al., "Drilling Down: An Examination of the Boom-Crime Relationship in Resource-Based Boom Counties," 3; Archbold, Dahle, and Jordan, "Policing 'The Patch': Police Response to Rapid Population Growth in Oil Boomtowns in Western North Dakota.," 2.

<sup>422</sup> "FBI—Crime Statistics."

property crime and theft can be attributed to the young males who migrated to Williston, some of whom struggled to travel to Williston because of their finances and are now reeling from a reduction of employment opportunities.

### **1. Indication of a Bust**

The primary emerging concerns for the Bakken area are its mounting debt and fiscal pressure as the boom turns into a bust. As it grew, the City of Williston invested in many long-term infrastructure projects. A decline in oil production caused a reduction in tax revenue, which has placed the area at risk of a massive bust. The City of Williston hired several employees to provide service to its growing population with city expenditures growing from just under \$20 million in 2008 to nearly \$180 million in 2014 (Figure 21). With the current trend indicating a growing disparity between revenue and expenditures, a concern has arisen that expenditures are outpacing available revenue. Consequently, additional loans from the Bank of North Dakota and reductions in reserve funds have also occurred (Figure 24) along with requests for an increase in sales and property taxes and additional user fees to alleviate the budget shortfall.<sup>423</sup>

With a need to refine the budget, community leaders have faced difficulty in prioritizing necessary infrastructure and investments that increase the quality of life and have the potential to retain or attract people to the community. Although the decision of where and when to invest city finances can be challenging, Williston may have been too reserved. Previous boom-and-bust experience may have affected the city's investment strategy by causing them to wait too long for some investments, but it appears they may have overinvested once they realized the need to act. The City of Williston was reserved in its actions because of the long-term debt from the past oil boom and bust;<sup>424</sup> however, as the unintended consequences of fracking mounted, community leaders made decisions to invest for the future. Research from NDSU indicated sustained long-term growth and a political desire to expand.<sup>425</sup> The City of Williston has presented an aggressive plan of

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<sup>423</sup> City of Williston, "Williston Energy Related Growth Impacts," 5.

<sup>424</sup> Killelea, "Boomtown USA," 26.

<sup>425</sup> Hodur and Bangsund, *Population Estimates for City of Williston*, 26.



investments (Figure 24), but a growing gap in funding is also apparent. City leaders presented a plan for closing that gap: a series of fee increases, sales and property tax increases, loans, and dependence on oil prices above \$50 per barrel for the 2015–2017 biennium, increasing to \$60–\$70 per barrel for the following bienniums until 2021.<sup>426</sup> The concern is what happens when oil prices fall short of projections and the city is saddled with even more debt while it continues to struggle to pay for current investment projects. The recent infrastructure expansion positions Williston well for the future only if oil prices meet or exceed the planning assumptions; otherwise, the increasing debt will be quite burdensome.

When Williston initially built its infrastructure, a long-term growth pattern surfaced. The challenge then was responding to and understanding how to manage the current build-out. Investing in nonessential services, such as a new airport even though trends showed a decline in boardings (Figure 23), as well as completing a \$70 million aquatic center, was tied to current and future tax collections. Budget shortfalls and mounting debt can threaten a city's financial solvency and bond rating. Moody's downgrading of Williston's bond rating would cost taxpayers additional money to leverage added infrastructure improvements.<sup>427</sup> That strain on the citizens of Williston exacerbated the cycle of financial stress.

Research on what has occurred in the Bakken strongly correlates with previous research on the boom-and-bust cycles associated with the extraction of natural resources, such as timber, fish, oil, gold, and silver. Based on the findings of this research, the concern is that the Bakken will face a long-term struggle, correlated with other historical boom-and-bust cycles: "Over the long-term, natural resource dependent communities experience relatively high rates of unemployment and poverty, instability, inequality, crime, and low educational attainment."<sup>428</sup> Although the long-term effects to Williston are still playing out at the time of this writing, weak governance of the boom-and-bust cycle made that community especially vulnerable to negative impacts.

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<sup>426</sup> City of Williston, "Williston Energy Related Growth Impacts," 4.

<sup>427</sup> Scheyder, "In North Dakota's Oil Patch, a Humbling Comedown."

<sup>428</sup> Jacquet, "Review of Risks to Communities from Shale Energy Development," 8322.

## **2. The Upside**

Infrastructure investment in the region and City of Williston has been a positive consequence of shale oil extraction in the Bakken. Not only has the investment provided current amenities, but the steps that Williston has taken will also create a community that is well prepared for future increases in oil demand. The newly constructed roads, houses, water treatment facilities, and general expansion of the community have prepared Williston for the return of higher oil prices, rising income, and the workers that follow. With the greater availability of houses, hotel rooms, commercial spaces, and city staff, many of the elements needed for Williston to prepare for, prevent, and mitigate negative socioeconomic impacts have been addressed.

## **3. Summary of Socioeconomic Impacts**

In the Bakken, particularly in the City of Williston, the community has followed the classic boom-and-bust cycle common to exploitation of natural resource. The impacts of population in-migration, housing shortages, income disparity, societal changes, crime, and political pressure must be balanced with taxpayer revenue. The challenge is that taxpayer investments have the potential for long-lasting consequences and must be done in a carefully measured manner. Only with a clear understanding of unintended consequences can a community best plan for and create ways to mitigate those challenges.

## **C. SUMMARY OF FINDINGS**

The individual findings surrounding several dependent variables have been discussed in this thesis, but examining all those variables and the associated boom-and-bust cycle of oil is critical for decision makers. The findings have been synthesized in Table 5, which shows the variables and how the boom-and-bust cycle affects them.

Table 5. Summary of Boom-and-Bust Relationship to Community Impacts.<sup>429</sup>

COMMUNITY IMPACTS	Boom		Bust		
		Environmental		Environmental	
		Positive	Negative	Positive	Negative
	Water Consumption	Income generated from permitting water usage	Declining groundwater levels can exacerbate future domestic growth.	Decrease in demand on the water ecosystem	Decline in income from water usage permits
	Groundwater Contamination	Data have indicated that aquifer has not experienced any leaks from wells.	The natural chemistry of groundwater has high salinity, creating difficulty discerning leaks.	Reduction of risk of contamination	The need for consistent long-term monitoring is difficult to maintain when production drops.
	Surface Water Contamination	Majority of past spills within containment areas decreased surface contamination.	Large quality spills occurred in the past; transparency was an issue.	Reduction of risk of contamination	
	Air Quality	North Dakota Public Health monitoring sites do not indicate air quality concerns at ground level.	High amounts of venting and flaring of natural gas because of lack of infrastructure	Decrease in amount of natural gas flared, decrease in truck traffic	Lack of income to invest in needed infrastructure, so practice of flaring and venting will continue
	Handling of Produced Water	No observable increase in seismic activity from deep well injection	The long-term effects of all the disposal wells are unknown. A risk of an eventual leak and contamination exists.	The decrease in drilling reduces the amount requiring disposal.	Increased concerns of illegal dumping of produced water as a cost-saving measure
		Socioeconomic		Socioeconomic	
		Positive	Negative	Positive	Negative
	Population Migration	Increase is community diversity and tax base	Strain on the pre-boom social system; unfamiliar people move into community.	Stabilization of community demographics to allow societal adjustment	The loss of tax base
	Housing Shortage	Investment opportunity	Increase is housing cost, especially rent	Stabilization of housing costs	Increase in risk of mortgage default and high vacancy rates
	Economic Impact	Increase in government tax collections	Increase dependence of tax collections; increase risk of long-term investments	Tax income stabilizes for more accurate planning	Increase in tax burden on the citizens

(continued on next page)

<sup>429</sup> Adapted from Dalton, *Discussion Paper—Potential Socioeconomic Effects of Unconventional Oil and Gas Development in Nova Scotia Communities*, 16.

Table 5. (Continued from previous page.)

<b>Community Growth</b>	Increase in community size and community amenities	Need for infrastructure and community services	Improved community planning	Increase in investor and citizen debt
<b>Employment / Income</b>	Increase in good-paying jobs and income levels	Competition of skilled employees inflates wages	Wages normalize, reducing high wages on small businesses	Increase in unemployment; decrease in personal income
<b>Crime Rate</b>	Increase in public safety staffing	Increase demand on public safety	Reduction of crime as workers leave	People seek illegal sources of income

## **VI. RECOMMENDATION AND CONCLUSION**

In preparing for battle I have always found that plans are useless, but planning is indispensable.

—Dwight D. Eisenhower

### **A. POLICY AND GUIDANCE RECOMMENDATIONS**

Based on this research, leaders and residents of communities who face potential boom-and-bust exploitation of natural resources must understand its consequences so they can perform proper and prudent planning and governance actions. In doing so, communities will be better prepared to mitigate the risks associated with natural resource-driven economic windfalls. This research addressed boom-and-bust consequences through a case study of the Bakken oil play and tackled the general issue of boom and bust by addressing the primary question: What are the effects of unconventional shale oil exploration on the Bakken communities? This paper aimed to provide decision makers and leaders with a clear analysis of the impacts so that they can make important policy and planning decisions. Based on this research, the following are recommended:

- Increased governance and regulation to mitigate adverse impacts
- Increased oversight through inspection and enforcement
- Proactive community planning and zoning
- Development of best practice
- Investment in transportation infrastructure
- Capitalization on the economic boom

#### **1. Increased Governance and Regulation**

The regulation of oil and gas production is conducted in individual states on nonfederal land. The inconsistencies created in these multiple jurisdictions have led to a states' rights issue. State governments are in essence pitted against one another to create more or less restrictive regulations in an attempt to prohibit or attract oil and gas

production in their own state. If all states were to adopt a standard regulation or best practice, the competition for either political interests or profit would be eliminated. Standardizing the governance and regulation of fracking would also provide local officials with better guidance to protect their resources.

Normalization of environmental fines for violations, including limiting the ability to reduce fines, would level the playing field and would convey the message that regulations are important and must be followed. To reduce fines for failing to follow safe practices or regulations is counterproductive to the protection, prevention, and mitigation of the risks associated with fracking.

Also, additional monitoring of water consumption, water quality, air quality, and traffic impacts on the local environment is recommended. The added monitoring would allow for the identification of emerging issues, so protective mitigation actions could be taken. To do so, more frequent sampling and testing is required. The identification of water contamination is difficult to discern because of the natural chemical make-up of water in the Bakken. The additional frequency of sampling and testing would provide the needed time to discover contamination and take steps for mitigation or recovery. Trends in deviations could be identified early by using prefracking site readings as a baseline standard.

## **2. Increased Oversight through Inspection and Enforcement**

Disparity among states in regard to inspection and enforcement rules is possible because states create their own rules. Standard inspection criteria and frequencies, based on industry safety standards, should be established. By defining frequency and criteria, each state would have common expectations and knowledge of inspection and enforcement. One recommended mandatory inspection should be a witnessed pressure test before the hydraulic fracturing process can begin. A required pressure test helps ensure that the casing and piping are securely intact.

The enforcement of fracking rules would increase transparency among the governing body, the regulatory agencies, and the oil companies. The intent of increased transparency is to raise citizens' confidence that fracking operations are conducted in a

safe and efficient manner. Standardizing fines and preventing any reduction in them would reinforce compliance with safety standards while discouraging companies that do not follow safe practices.

When a spill occurs, a required investigation with proper reporting and an enforcement mechanism must be implemented to ensure that the area is returned to preincident conditions. During the recovery process, a thorough investigation must take place to identify the cause and determine whether any regulations or standard best practices were ignored. If regulations or safe practices were circumvented, levying standard fines would help to mitigate future occurrences.

### **3. Proactive Community Planning and Zoning**

Haphazard planning significantly impacts a community's ability to capitalize on the short- and long-term economics of fracking. Research has shown that the City of Williston has been adversely impacted and will continue to be for several years by infrastructure investments, growth needs, and their associated debt. Williston's planning may have been conservative in the early years of the boom, but recent investments are not proactive. In contrast, the recommendation that communities implement prudent and proactive planning and zoning regulations is the only way to manage their growth, as well as their debt. The first step in a proactive plan is an impact plan for housing and infrastructure needs, financed by a surcharge when a permit is issued. Impact plans are used for analysis when making decisions on future investments.

Part of impact and comprehensive planning and zoning involves creating an allowance for temporary housing (man-camps). Temporary housing fulfills a critical need for the more transient oil-worker population. Bringing in temporary housing alleviates the demand for community expansion and new housing developments. Temporary housing also reduces the demand for significant infrastructure investment. To mitigate the risk of antisocial behavior in man-camps, strict antisocial and crime behavior rules should be implemented. A stipulation should be included that a violation will be cause for eviction from the housing, forfeiture of any deposit, and loss of employment.

The complexity of the boom-and-bust cycle requires communities to engage in planning and preparedness efforts to reduce adverse effects. Most communities lack the resources to prepare them adequately for the complexity of the challenges. To help combat this deficiency, outsourcing additional planning responsibilities can occur once indicators show that oil production has commenced. The benefit of outsourcing is that it provides greater impartiality and more objective, unemotional suggestion for the future. Contracted planners can assist, augment, or take over the planning services to avoid the hiring of long-term employees, which can delay planning efforts and mitigation strategies.

#### **4. Development of Best Practices**

Beyond the governance and enforcement aspects of fracking, a consensus is needed with regulators and the oil industry on the best practices to follow. Although research has indicated serious concerns affecting the environment, developing and following best practices could mitigate some of those risks. Examples of best practices include the following:

- Develop a method to ensure that retention ponds are constructed in a manner that prevents overflow caused by melting snow; for example, by raising berm levels. Instead of implementing this regulation for the entire industry, best practice would apply it to areas based on their risk.
- Find an alternative to the practice of venting or flaring of natural gas, which would mitigate the risk of an adverse effect on the environment. If the risk cannot be eliminated, a surcharge should be levied to pay for the future development of infrastructure that alleviates the air quality risk.
- Space monitoring sites by location and frequency to help ensure situational awareness of emerging problems. Monitoring of air and water is essential to ensure the public health of the region.
- Continue to develop safety procedures that reduce risks to the environment.
- Eliminate the practice of using disposal wells in known fault lines. The example of the Bakken illustrates that the practice can be performed in stable geological formations, but other areas of the country have problems with the disposal of produced water in injection wells.



## **5. Investment in Transportation Infrastructure**

The lack of infrastructure to transport oil and other necessary products to and from rural North Dakota has been problematic. Similarly, a lack of infrastructure to collect the natural gas contributes to air quality concerns. The lack of pipeline infrastructure also brings significant truck traffic that moves oil, produced water, and water. Each movement of product increases the risk of a spill. The additional movement has created the need for construction of roads in these remote areas, built to sufficient quality to withstand constant heavy truck traffic. Discussed in the literature review, difficulty has arisen in transporting the oil by rail. The lack of infrastructure raises the risks associated with movement of oil-related products.

Future investment in the necessary infrastructure could derive from an additional surcharge. A trigger point related to production levels could be set so the surcharge would appear after profits commence. The object of the surcharge would not be to burden startup developments but to have established producers help pay for the infrastructure that reduces environmental impact. A trigger point tied to production levels would allow wildcat (explorative) wells to be drilled without heavy financial burden; as wells produce, the surcharge would fund the infrastructure needed to service the industry responsibly.

## **6. Capitalization on the Economic Boom**

State and local governments must take advantage of the economic boom, so they can pay for the negative impacts. Implementing a special recovery fund is recommended, financed in part by oil tax collection. The fund would be used at both state and local levels with the explicit purpose of helping pay direct costs associated with oil production. North Dakota established a contingency fund, into which money was deposited beginning in September 2011. Within four years, the fund grew to \$3.2 billion but cannot be touched until 2017.<sup>430</sup> A similar fund would help reduce the burden of the boom-and-bust cycle associated with oil production. One mechanism to create the fund would be to establish a grant process, funded through the tax collection and accompanied by specific

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<sup>430</sup> “North Dakota Government Funds—The Office of North Dakota State Treasurer,” September 28, 2016, <http://www.nd.gov/treasurer/north-dakota-government-funds/>.

guidelines. The grant could be used to offset direct expenses caused by the impacts of fracking. In this manner, proceeds from the oil tax collection would be invested responsibly. Priority could even be given, such as to infrastructure needs, for example, water treatment facilities, roads, and pipelines.

With the in-migration of people comes the opportunity to develop property and attract taxpayers. New developments should be planned and zoned using a prudent business model. One suggestion is to have the developer and investors pay for the infrastructure needs, such as roads, water, sewer, and parks. Those costs can be passed along to the purchaser of the lot, minimizing the risk to local government and incentivizing the developer to develop and sell the lots. If and when a bust occurs, the risk shifts to the developer or current owner of the property, not the unvested local taxpayer.

The drain that shale oil production imposes on public safety resources could be combated with a public safety surcharge. The City of Williston has struggled with its retention of employees and an increase in the demand for services, so it has proposed such a public safety surcharge. The greatest challenge in retaining or increasing staffing of public safety professionals is competition for employment with the oil industry. A solution is to impose a surcharge to the citizens that would be used to retain and recruit people for critical public safety fields. Capitalizing on the profitability of oil production through the surcharge, a city could offer competitive public safety wages while also providing additional funds to expand emergency services that meet its increased population.

## **B. RECOMMENDATIONS FOR FUTURE RESEARCH**

Overall, the long-term environmental impacts are still relatively unknown. Although no groundwater contamination was identified in this research, the long-term impact from the use of disposal wells is unknown. Disposal wells currently serve a purpose. Without truly knowing the implications, however, the practice is concerning; and the consequences could be catastrophic. The next step would be to research those long-term effects on the environment.

Further research is also needed to refine and improve policy and governance. Fracking has recently been studied holistically, a necessary means because without evaluating the issues in a comprehensive framework, their full force may be unrecognized, particularly in regard to environmental impacts. Only through practical and prudent policy and governance can any unintended consequences be managed.

### **C. LIMITATIONS**

Data are critical to understanding the emerging impacts from fracking, and data and how they are located can be considered a limitation. In some instances, the data were easily obtained, such as the water consumption permits and amounts, the number of spills, community income, employment, housing units and vacancy, and demographics; however, some data were not representative of the current situation, such as FBI crime statistics most recently reported in 2012. Much of the census data also lagged behind the emerging trends. The census data indicated population and income increases, but the essence of what was occurring came from data obtained by regional news outlets in the Bakken. The discrepancy created a reliance on newspaper sources to obtain timely data. Although the use of higher quality research sources was preferred, the timeliest information was found at the local level.

Due to the complexity of shale oil exploration and consistently changing dynamics of society and the environment, the problems surrounding this issue will continue to evolve. Even as this research is released, new findings will emerge, especially related to the boom and bust of Williston and the State of North Dakota, which has been continually forced to make budget cuts resulting from falling oil revenue projections. At the release of this research, another developing issue is the protest of the Dakota Access Pipeline by the Standing Rock Sioux Tribe. As of late 2016, the Dakota Access Pipeline was nearly completed and designed to bring oil from the Bakken to Illinois. Although the pipeline infrastructure was necessary to reduce ongoing risk, the protest stems from the

belief that ancient burial grounds are being destroyed and drinking water is possibly at risk.<sup>431</sup>

A third limitation of this research is that some data sets may not be applicable to other shale oil formations. The more developed a community is before an oil boom, the less impactful the discovery of shale may be on that community. Having an infrastructure, such as a pipeline, can also reduce the impact on roads, air quality, and spill susceptibility. The lack of seismic activity in the Bakken should not be construed as a nonfinding for all disposal wells throughout the United States because other locations may be more vulnerable based on identified fault lines.

#### **D. CONCLUSION**

This research has a significant bearing on homeland security in its impact on the environment and the socioeconomic fabric of a community; concerns have arisen over public health and public safety for affected communities. Shale oil is a limited resource, and its exploration and extraction could be considered necessary because oil is an essential global commodity; but extracting the oil does not come without a price. This research indicates that unintended consequences spring from oil extraction, both environmentally and socioeconomically. The goal of this research was to provide local decision makers with an understanding of those unintended consequences and some recommendations that will allow them to prevent, prepare for, and mitigate the associated risks. Although the impacts continue to emerge, an evaluation of the effects on the Bakken can provide the next local community added insight to reducing the negative impacts of shale oil exploration.

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<sup>431</sup> “N.D. Pipeline Protester: ‘It’s About Our Rights as Native People’,” accessed October 8, 2016, <http://www.npr.org/2016/09/12/493532162/n-d-pipeline-protester-its-about-our-rights-as-native-people>; Holly Yan and Shawn Nottingham, “Tribe Files Emergency Request to Stop Dakota Access Pipeline Construction,” *CNN*, accessed October 8, 2016, <http://www.cnn.com/2016/09/05/us/dakota-access-pipeline/index.html>.

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